

# Risk Factors for Meniscal Tears: A Systematic Review Including Meta-analysis

**M**eniscal tears are commonly seen worldwide. In the Netherlands, the incidence of meniscal tears is 2 per 1000 patients per year.<sup>16</sup> Meniscal tears are responsible for an estimated 25 000 hospital admissions per year in England and Wales.<sup>5</sup> In the United States, arthroscopic partial meniscectomy after meniscal tear is the most frequent orthopaedic surgical procedure.<sup>20</sup> Meniscal tears lead to disability and time lost



from work, and their surgical treatment increases the long-term risk of knee osteoarthritis (OA) 4-fold.<sup>5,18,21,48</sup> A better understanding of meniscal tears and their causality can aid in diagnosing knee disorders.<sup>26,32</sup>

Despite its importance, little is known about the epidemiology of meniscal injury. A previously published systematic review by Reid et al<sup>46</sup> described, in addition to other knee disorders, risk factors for meniscal tears. The authors suggested that squatting, kneeling, crawling, chair sitting while driving, stair climbing, lifting items, and walking were all risk factors for meniscal tears. Reid et al<sup>46</sup> noted that kneeling was described as a risk factor in multiple studies, yet other factors were not described as such. McMillan and Nichols<sup>38</sup> systematically searched the literature to determine whether kneeling or squatting was causally associated with degenerative diseases of the knee. The authors concluded that work occupations involving frequent kneeling or squatting doubled the risk for developing knee OA. The authors of both articles limited their search to occupational settings and did not perform meta-analysis on the risk factors.

The elapsed time between anterior cruciate ligament (ACL) injury and reconstruction surgery has been identified

● **STUDY DESIGN:** Systematic review with meta-analysis.

● **OBJECTIVES:** To review and critically appraise the literature for factors that increase the risk for meniscal tears.

● **BACKGROUND:** Meniscal tears are an important cause of disability and time lost from work, and are associated with a 4-fold increase in the long-term risk of knee osteoarthritis. Knowledge of the risk factors that lead to meniscal tears can help to correctly diagnose knee injuries and is important to the development of prevention strategies for knee osteoarthritis.

● **METHODS:** A search of the Cochrane Database of Systematic Reviews, MEDLINE, and Embase, from 1950 to January 2012, and a hand search of reference lists of all initially selected studies, without restriction on language or date of publication, were conducted. Prospective, retrospective, and case-control studies that included individuals over 16 years of age, who had no previous meniscal injuries or surgeries, were selected. A meta-analysis for 17 risk factors was performed. Where considerable heterogeneity among studies was present or the data did not provide sufficient information to perform a meta-analysis, a qualitative synthesis was conducted.

● **RESULTS:** Eleven studies, with a total of 7358 participants, were selected for systematic review. Data were available for meta-analysis for 10 of the 11 studies. Qualitative analysis was conducted using data from 3 of the 11 studies. Results showed strong evidence that age (older than 60 years), gender (male), work-related kneeling and squatting, and climbing stairs (greater than 30 flights) were risk factors for degenerative meniscal tears. We also found strong evidence that playing soccer and playing rugby were strong risk factors for acute meniscal tears. Waiting longer than 12 months between the anterior cruciate ligament injury and reconstructive surgery was a strong risk factor for a medial meniscal tear but not for a lateral meniscal tear.

● **CONCLUSION:** The literature indicates a number of risk factors leading to either degenerative or acute meniscal tears, with some of these factors being potentially modifiable.

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● **KEY WORDS:** diagnosis, knee, meniscus, osteoarthritis

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as a risk factor for meniscal tears in multiple studies.<sup>1,12,14,24,30</sup> ACL injury leads to knee laxity and, consequently, a potentially unstable knee that is more susceptible to meniscal injury during dynamic abrupt movements. But the time from ACL injury to ACL surgery as a risk factor for meniscal tears in ACL-deficient knees has never been investigated in a systematic review with meta-analysis.

Identifying risk factors can help in establishing correct diagnoses of knee disorders and is important in the development of prevention strategies for knee OA. Previous systematic reviews have been limited to occupational knee disorders and have failed to include meta-analysis. Nor have previous studies assessed whether variation among original studies may be random or due to a systematic effect. Therefore, the purpose of this study was to conduct a systematic review of the literature for risk factors associated with meniscal tears and a meta-analysis for factors in homogeneous studies.

## METHODS

### Search Strategy

**A** SEARCH FOR RELEVANT ARTICLES was conducted in MEDLINE, Embase, and Cochrane Database of Systematic Reviews, from 1950 to January 2012, using the key words *tear, laceration, injury, lesion, laesion, torn, impairment, meniscus, menisci, meniscal injury, meniscal tear, meniscal laceration, meniscal lesion, risk, and predict*. The article types searched included randomized controlled trials, prospective and retrospective cohort studies, and case-control studies. The search was conducted without restrictions on language or date of publication. For articles written in an unknown foreign language, an interpreter with the specific language skills was employed to translate the article.

### Study Selection

To be included in the analysis, studies had to meet the following inclusion cri-

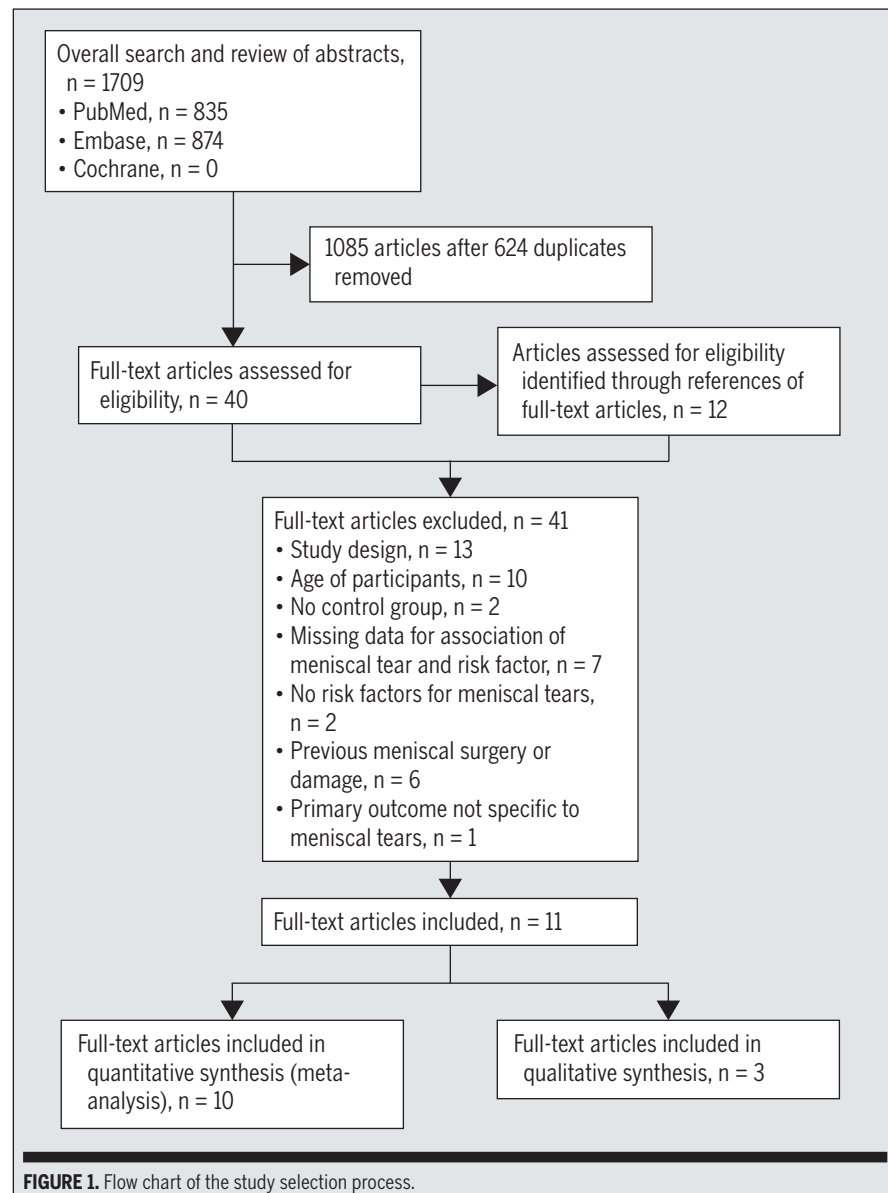


FIGURE 1. Flow chart of the study selection process.

teria: (1) the subjects had to be over 16 years of age and to have knee disorders; (2) the study had to be a randomized controlled trial, cohort study, or case-control study; and (3) the study had to describe risk factors for meniscal tears, including demographic, sport-related, lifestyle, and physical factors. Studies that included subjects with a history of previous meniscal injury or surgery were excluded. When a factor investigated in an identified study was associated with an increased incidence or prevalence of meniscal tears, the factor was classified

as a risk factor. Both risk factors and protective factors for meniscal tears were assessed. Based on the clinical course, risk factors were divided into 3 groups: degenerative meniscal tears, acute meniscal tears, and meniscal tears associated with knee laxity. Degenerative tears were considered to be due to exposure for a longer time. Acute tears were considered to occur as a result of a specific event (eg, sports). Joint laxity was either based on an assessment of systemic laxity using the Beighton scale or based on a history of an ACL tear.

# RESEARCH REPORT

TABLE 1

CHARACTERISTICS OF ALL INCLUDED STUDIES IN THIS SYSTEMATIC REVIEW ON RISK FACTORS FOR MENISCAL TEARS

Source	Study Design	Country, Setting	Participant Characteristics	Cases/Controls, n	Risk Factor
Baker et al <sup>5</sup>	Case-control	UK, 2 British hospitals	Healthy subjects, n = 703; sex (men/women, n), 196/47 cases (sex of controls unclear); age range, 20-59 y	202/333	Work-related squatting and kneeling
				202/333	Sitting, as a protective risk factor
				454/249	BMI
				202/333	Sport
				202/333	Standing or walking >2 h per d
				202/333	Driving >4 h per d
				202/333	Walking >2 mi per d
				202/333	Climbing >30 flights of stairs per d
				202/333	Lifting or carrying >10 kg >10 times per wk
				202/333	Lifting or carrying >25 kg >10 times per wk
Baker et al <sup>6</sup>	Case-control	UK, hospital center	Men with primary meniscal tear, n = 402; sex (men/women, n), 402/0; age range, 20-60 y	202/333	Work-related squatting and kneeling
				202/333	Sitting, as a protective risk factor
				202/333	Sport
				202/333	Standing or walking >2 h per d
				202/333	Driving >4 h per d
				202/333	Walking >2 mi per d
				202/333	Climbing >30 flights of stairs per d
				202/333	Lifting or carrying >10 kg >10 times per wk
				202/333	Lifting or carrying >25 kg >10 times per wk
				202/333	Lifting or carrying >50 kg >10 times per wk
Rytter et al <sup>50</sup>	Retrospective cohort	Denmark, 2 MRI centers	Floor layers and graphic designers, n = 141; sex (men/women, n), 141/0; age range, 42-70 y	92/49	Work-related squatting and kneeling
Fridén et al <sup>23</sup>	Retrospective cohort	Sweden, university hospital	Subjects with acute total ACL rupture, n = 100; sex unclear; age, <40 y	101/40	Age
Englund et al <sup>20</sup>	Prospective cohort	US, hospital center	Healthy ambulatory subjects, n = 991; sex (men/women, n), 426/565; age range, 50-90 y	426/565	Gender
				543/448	Age
				707/271	BMI
Taunton et al <sup>61</sup>	Retrospective cohort	Canada, primary care sports medicine facility	Athletes, n = 2002; sex (men/women, n), 926/1076; mean age, 43.2 y	926/1076	Gender
Church and Keating <sup>14</sup>	Retrospective cohort	UK, hospital center	Subjects after ACL reconstruction, n = 183; sex (men/women, n), 135/48; age range, 16-40 y	80/103 (MM + LM)	Time from ACL injury to ACL surgery
Kaeding et al <sup>29</sup>	Prospective cohort	US, 2 trauma centers and 1 referral center	Subjects with multiligament-injured knees, n = 2265; sex (men/women, n), 1394/871; mean $\pm$ SD age, 26 $\pm$ 9.5 y	643/1298 (MM + LM from ACL-only group)	Time from ACL injury to ACL surgery
Naranje et al <sup>41</sup>	Prospective cohort	India, hospital center	Patients with chronic ACL tears (injured >6 wk) who underwent ACL reconstruction, n = 50; sex (men/women, n), 46/4; age range, 18-48 y	29/21	Time from ACL injury to ACL surgery
Bhattacharyya et al <sup>7</sup>	Retrospective cohort	US, Boston University medical center	Men over 45 and women over 50 years of age, n = 204; sex (men/women, n), 157/47; age, >45 y	157/47	Gender
Yüksel et al <sup>57</sup>	Retrospective cohort	Turkey, military hospital	Military men 19-50 years of age, n = 317; sex (men/women, n), 317/0; age range, 19-50 y	156/161	Time from ACL injury to ACL surgery

Abbreviations: ACL, anterior cruciate ligament; BMI, body mass index; LM, lateral meniscus; MM, medial meniscus; MRI, magnetic resonance imaging.

After the initial search, 2 authors independently applied the selection criteria to potentially relevant studies from titles and abstracts only. After the first selection, the selection criteria were applied to the full-

text articles. Disagreements were resolved by consensus or, if disagreement persisted, by a third reviewer (E.B.). To locate additional articles, reference lists of all selected studies were carefully hand searched.

## Methodological Quality Assessment

For all included studies, a risk-of-bias table was used to identify potential sources of bias.<sup>27</sup> Items of the risk-of-bias table consisted of selection bias, information

TABLE 2

RISK-OF-BIAS SUMMARY TABLE  
OF ALL INCLUDED STUDIES\*

Article	Selection Bias <sup>†</sup>	Information Bias <sup>‡</sup>	Attrition Bias <sup>§</sup>	Confounding <sup>  </sup>
Baker et al <sup>15</sup>	-	-	-	-
Baker et al <sup>16</sup>	-	-	-	-
Rytter et al <sup>10</sup>	+	+	-	-
Fridén et al <sup>23</sup>	?	-	-	-
Englund et al <sup>20</sup>	-	-	-	-
Taunton et al <sup>61</sup>	-	?	-	-
Church and Keating <sup>14</sup>	-	?	-	-
Kaeding et al <sup>29</sup>	-	?	-	-
Naranje et al <sup>141</sup>	?	-	-	-
Bhattacharyya et al <sup>7</sup>	?	-	-	-
Yüksel et al <sup>67</sup>	?	-	-	-

\*Low risk of bias is presented as -, high risk of bias as +, and unclear risk of bias as ?. In the absence of described bias, the item was rated negative (-). If it was not clear if bias occurred and influenced the results in primary studies, the item was rated unclear (?).

<sup>†</sup>Selection bias was rated positive (+) if systematic differences occurred between baseline characteristics of the groups that were compared.

<sup>‡</sup>Information bias was rated positive (+) if systematic differences occurred between measurements of the groups that were compared.

<sup>§</sup>Attrition bias was rated positive (+) if systematic differences occurred between groups in withdrawals from a study.

<sup>||</sup>Confounding was rated positive (+) if in primary studies no adjustment was made for possible confounders.

bias, attrition bias, and confounding. We considered each item as low risk of bias, high risk of bias, or unclear risk of bias, based on the Cochrane Collaboration's tool for assessing risk of bias.<sup>27</sup>

### Data Extraction and Analysis

Data were extracted by 2 authors (B.S. and C.K.) independently. Extracted data consisted of population characteristics, risk estimate (odds ratio [OR]) adjusted for relevant confounders, information on statistical significance, and, where possible, a measure of precision of the point estimate (confidence interval [CI]). All results examined with meta-analysis were from binomial outcomes. Where studies were missing data, the corresponding authors were contacted. Risk factors were categorized as having strong evidence, moderate evidence, or minimal to no evidence, according to the following criteria. Factors with strong evidence doubled the risk for meniscal tears compared to baseline risk (OR>2.0) or had a strong protective effect (OR<0.8), and

were statistically significant ( $P<.05$ ); factors with moderate evidence had an OR between 1.5 and 2.0, or between 0.8 and 0.9 if protective, and were statistically significant ( $P<.05$ ), and if identified through qualitative analysis had an OR greater than 1.5 and were statistically significant ( $P<.05$ ); factors with minimal to no evidence had a nonsignificant OR ( $P>.05$ ) or presented no plausible explanation for being a risk factor for meniscal tears.

### Data Synthesis

Based on the expected homogeneity among studies, it was possible to perform a quantitative synthesis. For data analysis, univariate and multivariate outcome data were used. A pooled OR was calculated based on available data.

A meta-analysis was conducted to increase power and to calculate a pooled effect estimate. The standard error of the pooled effect estimate was used to assess the precision of the summary estimate of the individual studies by

CI. For meta-analysis, variation across studies must be considered. Heterogeneity was assessed by the  $P$  value of chi-square statistics and the  $I^2$  statistic using random-effects models. The  $I^2$  statistic describes the percentage of variability in effect estimates due to heterogeneity. We regarded heterogeneity as possibly unimportant when the  $I^2$  value was less than 40% and considerable when more than 75%.<sup>27</sup> ORs were calculated from 2-by-2 tables for each individual study. A pooled effect estimate was calculated as a weighted average of the effects estimated in the individual studies. The weights represent the amount of information from each study. Studies with larger sample sizes were weighted more heavily in meta-analysis than studies with smaller sample sizes. Meta-analysis was conducted using Review Manager 5 (The Nordic Cochrane Centre, Copenhagen, Denmark).<sup>27</sup>

When considerable heterogeneity between studies occurred or the data did not provide sufficient information to perform meta-analysis, a qualitative synthesis was conducted. The qualitative analysis was performed using the validity items of the standardized questionnaire for the appraisal of cohort studies, available on The Dutch Cochrane Centre website (<http://dcc.cochrane.org/dutch-cochrane-centre>). Each study received a total method score, which was the sum of all positive ratings on the questionnaire (0-10). A study was considered to be of high methodological quality when the total method score was equal to or above 6 points and to be of low methodological quality when the total method score was equal to or below 5 points.<sup>27</sup>

## RESULTS

### Selection of Studies

THE INITIAL SEARCH STRATEGY yielded 1709 articles, 11 of which were selected for quantitative as well as qualitative analysis. After removing 624 duplicate records, 1085



**TABLE 3**

## METHODOLOGICAL QUALITY ASSESSMENT OF STUDIES INCLUDED IN QUALITATIVE ANALYSIS\*

Authors	Quality Assessment Questions										Score
	1	2	3	4	5	6	7	8	9	10	
Fridén et al <sup>23</sup>	+	?	+	+	+	+	?	-	+	-	6
Baker et al <sup>5</sup>	+	+	+	+	+	-	?	+	+	+	8
Englund et al <sup>20</sup>	+	+	+	+	+	+	+	-	+	-	8

Quality assessment questions:

1. Was the study population clearly defined? Positive if at least the following items were given: place of recruitment, time period of recruitment, age, gender, and sampling frame.
2. Could selection bias be sufficiently excluded? Positive if the study population concerned a random sample of the source population with a participation rate at baseline of at least 80%, and, in cases of 2 or more groups, if groups were similar.
3. Was the exposure clearly defined? Positive if the intensity and duration of exposure were clearly described.
4. Was the exposure assessment adequate? Positive if the method used was standardized or valid (data presented or with reference).
5. Was the outcome clearly defined? Positive if the kind of meniscal tear was documented.
6. Was the outcome assessment method adequate? Positive if the outcome of meniscal tear was confirmed with magnetic resonance imaging or arthroscopy.
7. Was the outcome assessed blinded for the exposure status? Positive if the method used was performed in a blinded or masked fashion.
8. Was the follow-up period sufficiently long or, in retrospective studies, was the retrospective period sufficiently long? Positive if the baseline-to-follow-up time period was at least 1 year or, in retrospective studies, if the time period of retrospect was at least 1 year.
9. Could selective loss to follow-up be excluded? Positive if total number of dropouts/loss to follow-up was 20% or less or if the nonresponse was not selective (data shown).
10. Were the most important confounders identified and adequately considered in the study design and analysis? Positive if appropriate univariate or multivariate techniques were used, such as logistic regression analysis or survival analysis for dichotomous outcomes or linear regression analysis for continuous outcomes.

\*Negative outcome is presented as -, positive outcome as +, and unclear outcome as ?.

articles remained for screening based on title and abstract. Of these, 40 full-text articles were selected for further review. An additional 12 articles were identified from reference lists, yielding a total of 52 articles to assess for eligibility, as described in the Methods section. Based on the full-text appraisal, 41 articles were excluded. Consensus was immediately reached for 65% of the articles. For 35% of the articles, disagreement on whether to include the article for further analysis was resolved by consultation with B.S. and C.K. Eventually, 11 articles were included in the analysis, with 10 articles contributing to the meta-analysis<sup>5-7,14,20,29,41,50,61,67</sup> and 3 to the qualitative analysis<sup>5,20,23</sup> (2 articles being used in both the meta-analysis and the qualitative analysis).<sup>5,20</sup> The entire article-selection process is summarized in **FIGURE 1**.

### Characteristics of the Included Studies

Studies for this report consisted of 3 prospective cohort studies,<sup>20,29,41</sup> 6 retrospective cohort studies,<sup>7,14,23,50,61,67</sup> and 2 case-control studies<sup>5,6</sup> (**TABLE 1**). Three studies were conducted in the UK,<sup>5,6,14</sup> 3 in the United States,<sup>7,20,29</sup> and 1 each in Canada,<sup>61</sup> Denmark,<sup>50</sup> Sweden,<sup>23</sup> India,<sup>41</sup> and Turkey.<sup>67</sup> The age of participants ranged from 18 to 90 years. In total, 4135 men and 2663 women were included in the studies, with an additional 560 subjects for whom the sex was not reported, yielding a total of 7358 subjects. Characteristics of the studies are described in **TABLE 1**.

### Methodological Quality of Studies

All included studies were rated as high risk of bias, low risk of bias, or unclear risk of bias, according to the risk-of-bias table (**TABLE 2**).<sup>27</sup> For qualitative analysis,

all studies were rated as being of high methodological quality (**TABLE 3**).

### Heterogeneity

By analyzing the risk factors for meniscal tears separately, each study assessed the same exposure status and the same outcome, which reduced clinical diversity among studies (**TABLE 1**). According to the risk-of-bias table, methodological heterogeneity was not suspected (**TABLE 2**). The potential risk factors of age, gender, work-related kneeling and squatting, standing, walking, sitting, driving, climbing stairs, lifting or carrying heavy weights (greater than 10 kg and greater than 25 kg), soccer, rugby, running, swimming, other sports, and the amount of time between ACL injury and reconstruction surgery were pooled in meta-analysis (**TABLE 4**).

For the risk factors of body mass index (BMI), smoking, alcohol consumption, lifting weights (greater than 50 kg), weight bearing during trauma, and systemic joint laxity based on the Beighton scale, a qualitative analysis was conducted (**TABLE 3**). Qualitative analysis was necessary when heterogeneity was present or when the risk factor was only investigated in 1 study.

### Risk Factors

Meta-analysis was conducted for 24 subgroups, categorized according to degenerative meniscal tears, acute meniscal tears, and meniscal tears associated with knee laxity. ORs with 95% CIs are summarized in **TABLE 4**.

### Degenerative Meniscal Tears

**Body Mass Index** Pooling results from 2 articles revealed considerable heterogeneity ( $I^2 = 92\%$ ,  $P = .0004$ ).<sup>5,20</sup> Therefore, we decided to perform a qualitative analysis. In the study by Baker et al,<sup>5</sup> subjects with a BMI of 24 to 27 kg/m<sup>2</sup> and a BMI greater than 27 kg/m<sup>2</sup> were compared to subjects with a BMI less than 24 kg/m<sup>2</sup>. This provided ORs of 2.3 (95% CI: 1.5, 3.4) and 1.7 (95% CI: 1.2, 2.6), respectively. Calculating the overall OR for a

BMI greater than 24 kg/m<sup>2</sup> compared to a BMI less than 24 kg/m<sup>2</sup>, the OR was 5.83 (95% CI could not be calculated). In the study by Englund et al,<sup>20</sup> an OR of 1.43 was calculated for subjects with a BMI greater than 25 kg/m<sup>2</sup> compared to those with a BMI less than 25 kg/m<sup>2</sup>. Both studies did not adjust for possible confounders. We conclude that there is moderate evidence that a BMI greater than 25 kg/m<sup>2</sup> is an important risk factor for degenerative meniscal tears.

**Age** Four of the included articles reported data related to age. Two articles did not provide enough information to perform a meta-analysis.<sup>61,67</sup> Unfortunately, because we were unable to retrieve this information from the corresponding authors, only 2 articles were used in the meta-analysis.<sup>20,50</sup> Pooled analysis revealed that individuals who were over 60 years of age had significantly higher odds of developing degenerative meniscal tears than those who were under 60 years of age (OR = 2.32; 95% CI: 1.80, 3.01). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .32$ ) (FIGURE 2).

**Gender** Three of the included studies compared the influence of gender on meniscal tears.<sup>7,20,61</sup> The results indicated an almost 3-fold greater risk for men compared to women for degenerative meniscal tears (pooled OR = 2.98; 95% CI: 2.30, 3.85). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .87$ ) (FIGURE 2).

**Work-Related Kneeling and Squatting** Based on information from 3 articles,<sup>5,6,50</sup> pooled data revealed statistically significant evidence of an increased risk for degenerative meniscal tears in individuals who performed work involving kneeling or squatting more than 1 hour per day compared to those whose work does not involve kneeling or squatting (pooled OR = 2.69; 95% CI: 1.64, 4.40). Statistical heterogeneity was considered moderate ( $I^2 = 58\%$ ,  $P = .09$ ) (FIGURE 3).

**Sitting (Greater Than 2 Hours Per Day)** Two articles<sup>5,6</sup> compared individuals who sat more than 2 hours per day with those who sat less than 2 hours per day, with

TABLE 4	
SUMMARY TABLE FOR ORs PROVIDED IN META-ANALYSIS	
Condition/Risk Factor	OR (95% CI)
Degenerative meniscal tears	
Age (>60 y compared to <60 y)	2.32 (1.80, 3.01)
Gender (male compared to female)	2.98 (2.30, 3.85)
Work-related kneeling and squatting (>1 h compared to <1 h per d)	2.69 (1.64, 4.40)
Sitting (>2 h compared to <2 h per d)	0.68 (0.50, 0.92)
Driving (>4 h compared to <4 h per d)	1.37 (0.94, 1.98)
Standing or walking (>2 h compared to <2 h per d)	
Walking (>2 mi compared to <2 mi per d)	1.65 (1.22, 2.24)
Stair climbing (>30 flights compared to <30 flights per d)	2.28 (1.56, 3.31)
Lifting or carrying >10 kg (more than 10 times per wk)	1.89 (1.41, 2.55)
Lifting or carrying >25 kg (more than 10 times per wk)	1.58 (1.15, 2.16)
Acute meniscal tears	
Playing soccer (compared to nonsports participants for at least 12 mo prior to the onset of symptoms)	3.58 (1.87, 6.86)
Playing rugby (compared to nonsports participants for at least 12 mo prior to the onset of symptoms)	2.84 (1.48, 5.45)
Running (compared to nonsports participants for at least 12 mo prior to the onset of symptoms)	1.24 (0.74, 2.07)
Swimming (compared to nonsports participants for at least 12 mo prior to the onset of symptoms)	1.54 (1.09, 2.17)
Other sports (compared to nonsports participants for at least 12 mo prior to the onset of symptoms)	1.60 (1.17, 2.19)
Meniscal tears associated with knee laxity	
Time from ACL injury to surgery: medial meniscal tears (>12 mo compared with <12 mo from injury to ACL surgery)	3.50 (2.09, 5.88)
Time from ACL injury to surgery: lateral meniscal tears (>12 mo compared with <12 mo from injury to ACL surgery)	1.49 (0.94, 2.38)
Abbreviations: ACL, anterior cruciate ligament; CI, confidence interval; OR, odds ratio.	

a resulting OR of 0.68 (95% CI: 0.50, 0.92), indicating that those who sat more had a reduced risk of degenerative meniscal tears. Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .54$ ) (FIGURE 3).

**Driving (Greater Than 4 Hours Per Day)** Driving more than 4 hours per day compared to less than 4 hours per day for at least 12 months up to the onset of symptoms was analyzed in 2 articles.<sup>5,6</sup> The analysis yielded a nonsignificant OR of 1.37 (95% CI: 0.94, 1.98). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .39$ ) (FIGURE 3).

**Standing or Walking (Greater Than 2 Hours Per Day)** Based on data from 2 articles,<sup>5,6</sup> standing or walking more than 2 hours per day compared to less than 2 hours per day for at least 12 months up to the onset of symptoms increased the risk

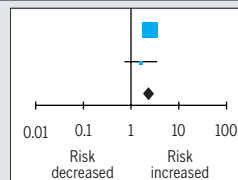
for degenerative meniscal tears, with an OR of 1.63 (95% CI: 1.17, 2.27). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .64$ ) (FIGURE 4).

**Walking (Greater Than 2 mi Per Day)** Meta-analysis from 2 articles<sup>5,6</sup> that compared walking more than 2 mi (3.2 km) per day to less than 2 mi per day for at least 12 months up to the onset of symptoms provided an OR of 1.65 (95% CI: 1.22, 2.24). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .40$ ) (FIGURE 4).

**Climbing Stairs (Greater Than 30 Flights Per Day)** Climbing more than 30 flights of stairs per day compared to less than 30 flights per day for at least 12 months up to the onset of symptoms was compared in 2 articles.<sup>5,6</sup> A statistically significant OR of 2.28 (95% CI: 1.56, 3.31) indicated

## Individuals Over 60 Years of Age Compared to Those 60 Years of Age and Under\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)
	Events	Total	Events	Total		
Englund et al <sup>20</sup>	240	543	110	448	89.1%	2.43 (1.85, 3.20)
Rytter et al <sup>50</sup>	28	40	60	101	10.9%	1.59 (0.73, 3.49)
Totals	268	583	170	549	100.0%	2.32 (1.80, 3.01)

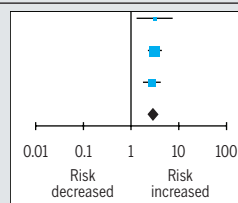


Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 1.00$ ,  $df = 1$  ( $P = .32$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 6.40$  ( $P < .00001$ ).

## Gender: Male Compared to Female\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)
	Events	Total	Events	Total		
Bhattacharyya et al <sup>7</sup>	143	157	36	47	8.7%	3.12 (1.31, 7.45)
Englund et al <sup>20</sup>	375	426	396	565	56.0%	3.14 (2.23, 4.42)
Taunton et al <sup>61</sup>	69	926	31	1076	35.2%	2.71 (1.76, 4.19)
Totals	587	1509	463	1688	100.0%	2.98 (2.30, 3.85)



Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.28$ ,  $df = 2$  ( $P = .87$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 8.32$  ( $P < .00001$ ).

**FIGURE 2.** Forest plots for age and gender as risk factors for degenerative meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

an increased risk for degenerative meniscal tears for those climbing more than 30 flights of stairs per day. Heterogeneity was considered unimportant ( $I^2 = 23\%$ ,  $P = .26$ ) (FIGURE 4).

**Lifting or Carrying Heavy Weights (Greater Than 10 kg More Than 10 Times Per Week)** The effects of lifting or carrying more than 10 kg more than 10 times per week were described in 2 articles.<sup>5,6</sup> Subjects who carried more than 10 kg compared to those who carried less than 10 kg for at least 12 months up to the onset of symptoms had 1.89 higher odds of developing degenerative meniscal tears (95% CI: 1.41, 2.55). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .36$ ) (FIGURE 5).

**Lifting or Carrying Heavy Weights (Greater Than 25 kg More Than 10 Times Per Week)** Based on the results of 2 articles,<sup>5,6</sup> lifting or carrying greater than 25 kg more than 10 times per week compared to carrying less than 25 kg for at least 12 months up to the onset of

symptoms was significantly associated with degenerative meniscal tears (OR = 1.58; 95% CI: 1.15, 2.16). Heterogeneity was considered unimportant ( $I^2 = 0\%$ ,  $P = .32$ ) (FIGURE 5).

**Lifting or Carrying Heavy Weights (Greater Than 50 kg More Than 10 Times Per Week)** Carrying heavy weights more than 50 kg more than 10 times per week compared to less than 50 kg for at least 12 months up to the onset of symptoms was only described as a risk factor in 1 article.<sup>5</sup> A statistically significant OR of 3.0 was calculated (95% CI: 1.7, 5.1). This OR was adjusted for BMI, joint laxity, and participation in sports, looking at their associations with occupational activities. When the OR was also adjusted for social class, it was 2.4 (95% CI: 1.4, 4.2), indicating moderate evidence that social class is associated with an increased risk for degenerative meniscal tears.

**Smoking** One study investigated smoking as a risk factor for degenerative meniscal tears.<sup>5</sup> Ex-smokers were compared

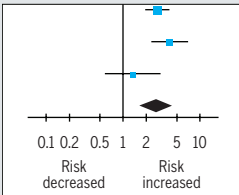
to nonsmokers, which provided a non-significant OR of 1.1 (95% CI: 0.7, 1.8). Also, current smokers were compared to nonsmokers, which yielded a similar OR of 1.3 (95% CI: 0.8, 2.0). Smoking was adjusted for BMI and joint laxity, as the authors of the primary study indicated that they were possible confounders.<sup>5</sup> We conclude that there is no evidence that smoking is a risk factor for meniscal tears.

**Alcohol Consumption** Based on data from 1 article,<sup>5</sup> alcohol consumption of 1 to 14 units per week compared to 0 units per week had an OR of 0.7 (95% CI: 0.4, 1.3) for degenerative meniscal tears. Consuming 15 or more units per week compared to 0 units per week yielded an OR of 0.9 (95% CI: 0.5, 1.6). Alcohol consumption was adjusted for BMI and joint laxity, as the authors of the primary study indicated that they were possible confounders.<sup>5</sup> We conclude that there is no evidence that alcohol consumption is associated with degenerative meniscal tears.

In summary, strong evidence for in-

### Work-Related Kneeling or Squatting Greater Than 1 Hour Per Day Compared to Those With No Work-Related Kneeling or Squatting\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)
	Events	Total	Events	Total		
Baker et al <sup>5</sup>	129	202	129	333	44.3%	2.79 (1.95, 4.01)
Baker et al <sup>6</sup>	43	67	103	335	33.7%	4.04 (2.33, 7.00)
Rytter et al <sup>50</sup>	74	92	37	49	21.9%	1.33 (0.58, 3.06)
Totals	246	361	269	717	100.0%	2.69 (1.64, 4.40)

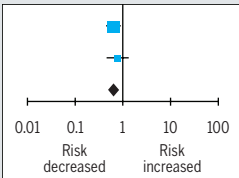


Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.11$ ,  $\chi^2 = 4.76$ ,  $df = 2$  ( $P = .09$ ),  $I^2 = 58\%$ . Test for overall effect:  $Z = 3.94$  ( $P < .0001$ ).

### Sitting for More Than 2 Hours Per Day Compared to Sitting Less Than 2 Hours Per Day for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)
	Events	Total	Events	Total		
Baker et al <sup>5</sup>	112	202	220	333	69.1%	0.64 (0.45, 0.91)
Baker et al <sup>6</sup>	26	67	150	335	30.9%	0.78 (0.46, 1.34)
Totals	138	269	370	668	100.0%	0.68 (0.50, 0.92)

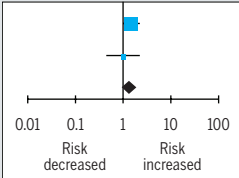


Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.38$ ,  $df = 1$  ( $P = .54$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 2.53$  ( $P = .01$ ).

### Driving More Than 4 Hours Per Day Compared to Less Than 4 Hours Per Day for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)
	Events	Total	Events	Total		
Baker et al <sup>5</sup>	52	202	63	333	78.9%	1.49 (0.98, 2.26)
Baker et al <sup>6</sup>	8	67	40	335	21.1%	1.00 (0.45, 2.25)
Totals	60	269	103	668	100.0%	1.37 (0.94, 1.98)



Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.73$ ,  $df = 1$  ( $P = .39$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 1.65$  ( $P = .10$ ).

**FIGURE 3.** Forest plots for kneeling/squatting, sitting, and driving as risk factors for degenerative meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

creased risk for degenerative meniscal tears was found for the following factors: older age (greater than 60 years), being male, work-related kneeling and squatting, and climbing stairs. Strong evidence was also found to suggest that sitting longer than 2 hours per day was protective of degenerative meniscal tears. Moderate evidence was found for higher BMI (greater than 25 kg/m<sup>2</sup>), standing, walking, and lifting or carrying heavy weights (greater than 10 kg, greater than 25 kg, and greater than 50

kg) as risk factors leading to degenerative meniscal tears. We found minimal or no evidence that driving, smoking, and alcohol consumption were associated with the incidence of degenerative meniscal tears.

### Acute Meniscal Tears

**Weight Bearing During Trauma** The risk factor of weight bearing during trauma was studied in 1 article.<sup>23</sup> When compared to no weight bearing during trauma, weight bearing during trauma

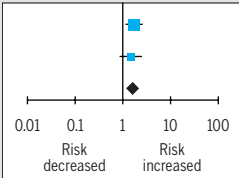
had an OR of 4.5 (95% CI could not be computed). There was no adjustment for possible confounders. We conclude that there is moderate evidence that weight bearing during trauma is an important risk factor for acute meniscal tears, although it is unclear whether the OR of 4.5 is statistically significant.

**Sport** Overall, sport seems to be a relevant risk factor for acute meniscal tears. From the information provided in 2 articles,<sup>5,6</sup> we analyzed the following types of sport separately: soccer, rugby, running, swimming,



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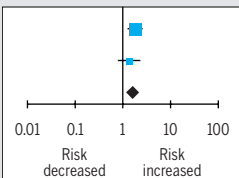
## Standing or Walking More Than 2 Hours Per Day Compared to Less Than 2 Hours Per Day for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	161	202	231	333	63.2%	1.73 (1.15, 2.62)	
Baker et al <sup>6</sup>	43	67	184	335	36.8%	1.47 (0.85, 2.53)	
Totals	204	269	415	668	100.0%	1.63 (1.17, 2.27)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.22$ ,  $df = 1$  ( $P = .64$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 2.91$  ( $P = .004$ ).

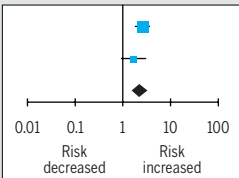
## Walking More Than 2 mi Per Day Compared to Less Than 2 mi Per Day for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	140	202	185	333	68.7%	1.81 (1.25, 2.61)	
Baker et al <sup>6</sup>	25	67	102	335	31.3%	1.36 (0.79, 2.35)	
Totals	165	269	287	668	100.0%	1.65 (1.22, 2.24)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.71$ ,  $df = 1$  ( $P = .40$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 3.22$  ( $P = .001$ ).

## Climbing More Than 30 Flights of Stairs Per Day Compared to Less Than 30 for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	102	202	94	333	68.3%	2.59 (1.80, 3.73)	
Baker et al <sup>6</sup>	18	67	59	335	31.7%	1.72 (0.93, 3.16)	
Totals	120	269	153	668	100.0%	2.28 (1.56, 3.31)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.02$ ,  $\chi^2 = 1.29$ ,  $df = 1$  ( $P = .26$ ),  $I^2 = 23\%$ . Test for overall effect:  $Z = 4.29$  ( $P < .0001$ ).

**FIGURE 4.** Forest plots for standing, walking, and stair climbing as risk factors for degenerative meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

and other sports. The reference group consisted of people who were not exposed to sport in the previous 12 months.

**Soccer** The OR of sustaining acute meniscal tears related to playing soccer was 3.58 (95% CI: 1.87, 6.86). The statistical heterogeneity was considered substantial ( $I^2 = 71\%$ ,  $P = .06$ ). Yet the  $I^2$  was lower than 75%, and, given the inability to perform a subgroup analysis based on 2 articles, a meta-analysis was conducted (FIGURE 6).

**Rugby** Although the outcomes of the study by Baker et al<sup>5</sup> were not significant, the overall risk of acute meniscal tears

related to playing rugby was significant, with an OR of 2.84 (95% CI: 1.48, 5.45). Statistical heterogeneity is considered not important ( $I^2 = 0\%$ ,  $P = .70$ ) (FIGURE 6).

**Running** Pooled data from 2 studies<sup>5,6</sup> revealed no statistically significant evidence (OR = 1.24; 95% CI: 0.74, 2.07) of association with acute meniscal tears. There was no important statistical heterogeneity ( $I^2 = 0\%$ ,  $P = .76$ ) (FIGURE 7).

**Swimming** Although the 2 primary studies<sup>5,6</sup> had barely significant and not significant values, the pooled data revealed a statistically significant outcome for

swimming as a risk factor for meniscal tears (OR = 1.54; 95% CI: 1.09, 2.17). We found no important statistical heterogeneity ( $I^2 = 0\%$ ,  $P = .87$ ) (FIGURE 7).

**Other Sports** Unfortunately, the primary studies<sup>5,6</sup> did not define what “other sports” included. Nevertheless, an OR of 1.60 (95% CI: 1.17, 2.19) would indicate that sport activities are a risk factor for acute meniscal tears. Statistical heterogeneity was considered not important ( $I^2 = 11\%$ ,  $P = .29$ ) (FIGURE 7).

In summary, strong evidence for an increased risk for meniscal tears was

#### Lifting or Carrying More Than 10 kg More Than 10 Times Per Week Compared to Controls for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	125	202	146	333	68.8%	2.08 (1.45, 2.97)	
Baker et al <sup>6</sup>	31	67	120	335	31.2%	1.54 (0.91, 2.62)	
Totals	156	269	266	668	100.0%	1.89 (1.41, 2.55)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.84$ ,  $df = 1$  ( $P = .36$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 4.23$  ( $P < .0001$ ).

#### Lifting or Carrying More Than 25 kg More Than 10 Times Per Week Compared to Controls for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	78	202	88	333	70.5%	1.75 (1.21, 2.54)	
Baker et al <sup>6</sup>	20	67	86	335	29.5%	1.23 (0.69, 2.20)	
Totals	98	269	174	668	100.0%	1.58 (1.15, 2.16)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 1.00$ ,  $df = 1$  ( $P = .32$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 2.84$  ( $P = .004$ ).

**FIGURE 5.** Forest plots for lifting or carrying as a risk factor for degenerative meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

#### Soccer Players Compared to Nonsports Participants for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	61	202	47	333	53.6%	2.63 (1.71, 4.05)	
Baker et al <sup>6</sup>	36	67	62	335	46.4%	5.11 (2.94, 8.90)	
Totals	97	269	109	668	100.0%	3.58 (1.87, 6.86)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.16$ ,  $\chi^2 = 3.44$ ,  $df = 1$  ( $P = .06$ ),  $I^2 = 71\%$ . Test for overall effect:  $Z = 3.85$  ( $P = .0001$ ).

#### Rugby Players Compared to Nonsports Participants for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	7	202	5	333	31.6%	2.35 (0.74, 7.52)	
Baker et al <sup>6</sup>	11	67	20	335	68.4%	3.09 (1.41, 6.81)	
Totals	18	269	25	668	100.0%	2.84 (1.48, 5.45)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.15$ ,  $df = 1$  ( $P = .70$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 3.13$  ( $P = .002$ ).

**FIGURE 6.** Forest plots for soccer and rugby as risk factors for acute meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

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## Runners Compared to Nonsports Participants for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	19	202	27	333	70.2%	1.18 (0.64, 2.18)	
Baker et al <sup>6</sup>	6	67	22	335	29.8%	1.40 (0.54, 3.59)	
Totals	25	269	49	668	100.0%	1.24 (0.74, 2.07)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.09$ ,  $df = 1$  ( $P = .76$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 0.82$  ( $P = .41$ ).

## Swimmers Compared to Nonsports Participants for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	58	202	70	333	73.1%	1.51 (1.01, 2.26)	
Baker et al <sup>6</sup>	14	67	47	335	26.9%	1.62 (0.83, 3.15)	
Totals	72	269	117	668	100.0%	1.54 (1.09, 2.17)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.00$ ,  $\chi^2 = 0.03$ ,  $df = 1$  ( $P = .87$ ),  $I^2 = 0\%$ . Test for overall effect:  $Z = 2.46$  ( $P = .01$ ).

## Participants in Other Sports Compared to Nonsports Participants for at Least 12 Months Prior to the Onset of Symptoms\*

Study	Cases		Controls		Weight	OR IV, Random (95% CI)	
	Events	Total	Events	Total			
Baker et al <sup>5</sup>	112	202	155	333	67.4%	1.43 (1.01, 2.03)	
Baker et al <sup>6</sup>	38	67	132	335	32.6%	2.02 (1.19, 3.43)	
Totals	150	269	287	668	100.0%	1.60 (1.17, 2.19)	

Abbreviations: CI, confidence interval; IV, instrumental variables estimation; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.01$ ,  $\chi^2 = 1.12$ ,  $df = 1$  ( $P = .29$ ),  $I^2 = 11\%$ . Test for overall effect:  $Z = 2.91$  ( $P = .004$ ).

**FIGURE 7.** Forest plots for running, swimming, and other sports as risk factors for acute meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

found for the factors of playing soccer and playing rugby. Moderate evidence was found for weight bearing during trauma, swimming, and other sports. We found minimal evidence for running as a risk factor.

## Meniscal Tears Associated With Knee Laxity

**Systemic Joint Laxity** Based on the results of 1 study<sup>5</sup> that used the Beighton scale to estimate systemic joint laxity, individuals with a score of 1 compared to a score of 0 on the scale had a greater OR

for meniscal tears (OR = 1.9; 95% CI: 1.2, 3.0). This risk did not rise progressively as scores on the Beighton scale increased to 2 and higher (OR = 1.9; 95% CI: 1.3, 2.9). There was no adjustment for possible confounders. We found moderate evidence that systemic joint laxity is a risk factor for meniscal tears.

**Time From ACL Injury to ACL Surgery: Medial Meniscal Tears** Eight articles were potentially eligible for our meta-analysis. We were unable to obtain information to calculate an OR and to perform meta-analysis for 4 of the arti-

cles.<sup>1,8,58,62</sup> The remaining 4 articles<sup>14,29,41,67</sup> provided an overall OR of 3.50 (95% CI: 2.09, 5.88) for medial meniscal tears when ACL surgery was performed more than 12 months after the ACL injury compared to less than 12 months after ACL injury. Statistical heterogeneity was considered substantial ( $I^2 = 73\%$ ,  $P = .01$ ) (FIGURE 8).

**Time From ACL Injury to ACL Surgery: Lateral Meniscal Tears** Four of the 8 relevant articles were also excluded from the meta-analysis due to missing data.<sup>1,8,58,62</sup> The remaining 4 articles pro-

#### Medial Meniscus: More Than 12 Months Compared to Less Than 12 Months\*

Study	Cases		Controls		Weight	OR M-H, Random (95% CI)	
	Events	Total	Events	Total			
Church and Keating <sup>14</sup>	41	80	25	103	24.7%	3.28 (1.75, 6.15)	
Kaeding et al <sup>29</sup>	401	643	538	1298	36.9%	2.34 (1.93, 2.84)	
Naranje et al <sup>41</sup>	18	21	16	29	9.9%	4.88 (1.17, 20.26)	
Yüksel et al <sup>67</sup>	124	156	66	161	28.5%	5.58 (3.38, 9.19)	
Totals	584	900	645	1591	100.0%	3.50 (2.09, 5.88)	

Abbreviations: CI, confidence interval; M-H, Mantel-Haenszel method; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.18$ ,  $\chi^2 = 11.21$ ,  $df = 3$  ( $P = .01$ ),  $I^2 = 73\%$ . Test for overall effect:  $Z = 4.75$  ( $P < .00001$ ).

#### Lateral Meniscus: More Than 12 Months Compared to Less Than 12 Months\*

Study	Cases		Controls		Weight	OR M-H, Random (95% CI)	
	Events	Total	Events	Total			
Church and Keating <sup>14</sup>	25	80	22	103	22.1%	1.67 (0.86, 3.26)	
Kaeding et al <sup>29</sup>	323	643	659	1298	37.6%	0.98 (0.81, 1.18)	
Naranje et al <sup>41</sup>	15	21	12	29	11.0%	3.54 (1.07, 11.77)	
Yüksel et al <sup>67</sup>	96	156	78	161	29.3%	1.70 (1.09, 2.66)	
Totals	459	900	771	1591	100.0%	1.49 (0.94, 2.38)	

Abbreviations: CI, confidence interval; M-H, Mantel-Haenszel method; OR, odds ratio.

\*Heterogeneity:  $\tau^2 = 0.14$ ,  $\chi^2 = 10.25$ ,  $df = 3$  ( $P = .02$ ),  $I^2 = 71\%$ . Test for overall effect:  $Z = 1.68$  ( $P = .09$ ).

**FIGURE 8.** Forest plots for time between an anterior cruciate ligament injury and reconstruction as a risk factor for meniscal tears. The squares represent point estimates from each cohort; bigger squares indicate larger samples and the lines are 95% CIs. The diamond represents the pooled ratio (vertical tips) and pooled 95% confidence interval (horizontal tips).

vided data for a meta-analysis.<sup>14,29,41,67</sup> An overall OR of 1.49 was found when ACL surgery was provided more than 12 months after ACL injury compared to less than 12 months after ACL injury, but it was not statistically significant (95% CI: 0.94, 2.38). Statistical heterogeneity was substantial, with an  $I^2$  value of 71% ( $P = .02$ ) (FIGURE 8).

In summary, strong evidence for an increased risk for medial meniscal tears was found when time between ACL injury and reconstruction surgery was greater than 12 months. Moderate evidence was found for systemic joint laxity of 1 or more on the Beighton scale being a risk factor for meniscal tears. Minimal to no evidence was found for the amount of time between ACL injury and reconstruction surgery being a risk factor associated with lateral meniscal tears.

## DISCUSSION

**W**E SYSTEMATICALLY SEARCHED the literature for studies that reported risk factors for meniscal tears. Eleven studies met our inclusion criteria, of which 10 contributed to meta-analysis and 3 to qualitative analysis. The conclusions of these analyses were based on a total sample of 7358 individuals who participated in the 11 studies analyzed.

This literature review provides strong evidence that age (greater than 60 years), gender (being male), work-related kneeling and squatting, and climbing stairs (greater than 30 flights) are risk factors for degenerative meniscal tears. Moderate evidence was found for BMI (greater than 25 kg/m<sup>2</sup>), walking (greater than 2 mi), standing (greater than 2 hours per day), and lifting or carrying heavy weights

(greater than 10 kg, greater than 25 kg, greater than 50 kg) as risk factors. There was minimal to no evidence for driving (greater than 4 hours per day), smoking, and alcohol consumption as risk factors. Finally, there was strong evidence that sitting greater than 2 hours per day reduces risks of degenerative meniscal tears.

For acute meniscal tears, there was strong evidence that playing soccer and playing rugby are risk factors. Moderate evidence was found for weight bearing during trauma, swimming, and participation in other sports as risk factors. Finally, there was minimal evidence for running as a risk factor for acute meniscal tears.

The literature investigating the association between joint laxity and the risk of meniscal tears indicated that there is moderate evidence linking systemic laxity, rated as a score of 1 or higher on the

Beighton scale, and an increased incidence of meniscal injuries. There is also strong evidence that waiting longer than 12 months between ACL injury and reconstruction surgery is a risk factor for tear of the medial meniscus, but there is no evidence of such an association for the lateral meniscus.

Previously, McMillan and Nichols<sup>38</sup> described kneeling and squatting as a risk factor for meniscal tears in mine workers (25–54 years). In this specific population, a 4-fold higher risk (OR = 4.0, 95% CI unknown) was found for meniscal tears compared to the general population. The reported prevalence of 10.4% for meniscal tears among miners was presumably caused by kneeling.<sup>38</sup> In contrast, we found an overall OR for meniscal tears for work-related kneeling and squatting of 2.69 (95% CI: 1.64, 4.40). This effect estimate is lower than the one reported by McMillan and Nichols,<sup>38</sup> for several reasons. The studies included in the review by McMillan and Nichols<sup>38</sup> were also identified by our literature search but were excluded in our review because they were not cohort or case-control studies,<sup>3</sup> or because the age of the participants was not greater than 16 years.<sup>54</sup> Also, the review by McMillan and Nichols<sup>38</sup> focused on risk factors for knee OA as the primary outcome. A separate systematic review by Reid et al<sup>46</sup> concluded that squatting should be considered an occupationally based risk factor, which is consistent with our findings.

Similar to squatting and kneeling, the other risk factors for degenerative meniscal tears, such as lifting or carrying heavy weights and climbing stairs, are likely related to an increased mechanical loading on the knee during these activities. Accordingly, our review leads to the conclusion that sitting is a protective factor for meniscal tears, which is contrary to the findings by Baker et al,<sup>5</sup> who reported an increase in risk with driving; however, this might have been, as the authors suggested, a spurious finding.

The present review found moderate evidence for BMI as a risk factor for

degenerative meniscal tears. Due to the heterogeneity of the data, a qualitative analysis was conducted. When individuals with a BMI of 24 to 27 kg/m<sup>2</sup> and those with a BMI greater than 27 kg/m<sup>2</sup> were separately compared to those with a BMI less than 24 kg/m<sup>2</sup>, the ORs were 2.3 (95% CI: 1.5, 3.4) and 1.7 (95% CI: 1.2, 2.6), respectively.<sup>5</sup> In another study included in the present systematic review, individuals with a BMI greater than 25 kg/m<sup>2</sup> had an increased risk for meniscal tears compared to those with a BMI less than 25 kg/m<sup>2</sup> (OR = 1.43).<sup>20</sup> Laberge et al<sup>35</sup> found significantly greater prevalence rates of meniscal tears (76% and 74%, respectively) in individuals who were overweight (BMI 25–30 kg/m<sup>2</sup>) or obese (BMI greater than 30 kg/m<sup>2</sup>), compared to 34% in individuals with a BMI less than 25 kg/m<sup>2</sup> ( $P = .03$ ). The higher risk reported by Laberge et al<sup>35</sup> could be explained by the fact that their population was older (45–55 years of age) and, therefore, already had a higher risk for degenerative meniscal tears.

As expected, we found a significantly increased risk for acute meniscal tears in individuals who participated in sports such as rugby (OR = 2.84; 95% CI: 1.48, 5.45) and soccer (OR = 3.58; 95% CI: 1.87, 6.86). This higher risk for meniscal tears may be related to the frequent occurrence of a combination of greater weight-bearing stresses and twisting moments occurring on a semiflexed knee during such sports.<sup>17</sup> In contrast, running, despite the need for greater load absorption by the menisci, was not a risk factor.<sup>51</sup> This could be explained by the absence of pivoting motion on a semiflexed knee during running and the lack of contact with other players.

Multiple studies have indicated that a longer time between ACL injury and surgical reconstruction leads to an increased risk of meniscal tears.<sup>12,14,29,30,41,44,67</sup> This literature review is consistent with these findings for injuries to the medial, but not the lateral, meniscus. Because the lateral meniscus is not as firmly attached

to the joint capsule as the medial meniscus, the lateral meniscus is more mobile, which may explain this difference.<sup>63</sup>

The strengths of this systematic review include a search strategy that made use of 3 electronic databases, searching the gray literature, and hand searching the references of all included studies without restrictions on language or date of publication. Patients of the primary studies were, except for those with ACL injuries, all from the general population or general practice settings. Therefore, findings are representative of the general population. All factors reported in this review have previously been described in individual studies or in systematic reviews but were never analyzed with meta-analysis methods.<sup>38,46</sup>

Our systematic review is limited by the fact that most of the findings were derived from a very small number of studies. This was, in part, the result of excluding articles based on study design<sup>3,9,10,12,38,47,49,51–53,63,64,66</sup> and the age of participants.<sup>13,30,31,36,37,40,44,54,57,60</sup> For a factor to be considered as a “risk” for meniscal tears, the prospective and retrospective period of exposure to the risk had to be sufficiently long. A plausible time of exposure is necessary for a causal relationship between risk factor and meniscal tear, according to the criteria for causality by Hill.<sup>28</sup> Therefore, we excluded cross-sectional studies. Also, we set strict inclusion and exclusion criteria on age, as other factors may be associated with an increased risk for meniscal tears in children compared to adolescents and adults.<sup>2</sup>

The results of this systematic review may be helpful in better understanding the factors that lead to meniscal tears. Also, these risk factors can be used to design preventive strategies for knee OA. To improve the diagnostic accuracy of meniscal pathology, it could be beneficial to consider risk factors. We recommend that future studies assess whether combining these risk factors with clinical diagnostic tests could improve accuracy in the diagnosis of meniscal tears.



## CONCLUSION

**F**OR DEGENERATIVE MENISCAL TEARS, this literature review provides strong evidence that age (greater than 60 years), gender (being male), work-related kneeling and squatting, and climbing stairs (greater than 30 flights) are risk factors for meniscal tears. Also, there was strong evidence that sitting greater than 2 hours per day may reduce the risk of degenerative meniscal tears. For acute meniscal tears, there was strong evidence that playing soccer and playing rugby are risk factors. There was also strong evidence that waiting more than 12 months between ACL injury and reconstruction surgery is a risk factor for a tear of the medial meniscus. ●

## KEY POINTS

**FINDINGS:** For degenerative meniscal tears, this literature review provides strong evidence that age (greater than 60 years), gender (being male), work-related kneeling and squatting, and climbing stairs (greater than 30 flights) are risk factors for meniscal tears. Also, there was strong evidence that sitting more than 2 hours per day reduces risks of degenerative meniscal tears. For acute meniscal tears, there was strong evidence that playing soccer and playing rugby are risk factors. There was also strong evidence that waiting more than 12 months between ACL injury and reconstruction surgery is a risk factor for a tear of the medial meniscus.

**IMPLICATIONS:** Identifying risk factors is important for prevention strategies and can aid in establishing a correct diagnosis.

**CAUTION:** The study is limited by the small number of studies for each risk factor included in the review. The limited number of studies was partially due to a stringent selection based on study design and the age of participants.

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