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Review

Knee extensor muscle weakness is a risk factor for development of knee osteoarthritis. A systematic review and meta-analysis

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S U M M A R Y

The objective of this study was to perform a systematic review and meta-analysis on the association between knee extensor muscle weakness and the risk of developing knee osteoarthritis. A systematic review and meta-analysis was conducted with literature searches in Medline, SPORTDiscus, EMBASE, CINAHL, and AMED. Eligible studies had to include participants with no radiographic or symptomatic knee osteoarthritis at baseline; have a follow-up time of a minimum of 2 years, and include a measure of knee extensor muscle strength. Hierarchies for extracting data on knee osteoarthritis and knee extensor muscle strength were defined prior to data extraction. Meta-analysis was applied on the basis of the odds ratios (ORs) of developing symptomatic knee osteoarthritis or radiographic knee osteoarthritis in subjects with knee extensor muscle weakness. ORs for knee osteoarthritis and 95% confidence intervals (CI) were estimated and combined using a random effects model. Twelve studies were eligible for inclusion in the meta-analysis after the initial searches. Five cohort studies with a follow-up time between 2.5 and 14 years, and a total number of 5707 participants (3553 males and 2154 females), were finally included. The meta-analysis showed an overall increased risk of developing symptomatic knee osteoarthritis in participants with knee extensor muscle weakness (OR 1.65 95% CI 1.23, 2.21; $I^2 = 50.5\%$). This systematic review and meta-analysis showed that knee extensor muscle weakness was associated with an increased risk of developing knee osteoarthritis in both men and women.

Introduction

Individuals with knee osteoarthritis have shown knee extensor muscle weakness compared to control subjects[1–3]. Individual studies have reported knee extensor muscle weakness to be a risk factor for knee osteoarthritis, particularly in women[4–6]. In a recent review of the literature investigating quadriceps muscle weakness and the risk of developing knee osteoarthritis, it was concluded that greater quadriceps muscle strength seemed to be related to lower risk of incident symptomatic, but not radiographic knee osteoarthritis[7]. Other reviews have discussed the role of impaired muscle function as a risk factor for development of knee osteoarthritis, but no firm conclusions have been drawn[8,9]. Increased knowledge about whether knee extensor muscle weakness is a risk factor for knee osteoarthritis or not is important, as muscle strength is a potential modifiable risk factor. To our knowledge, no systematic review and meta-analysis has been conducted to ascertain this. The objective of this study was to perform a systematic review and meta-analysis to investigate if knee extensor muscle weakness was associated with increased risk of developing knee osteoarthritis in men and women.

Material and methods

Protocol

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement was used as a guideline for this

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study. The study protocol is registered in PROSPERO (International prospective register of systematic reviews), with registration number CRD42013005607 (http://www.crd.york.ac.uk/prospero/).

Eligibility criteria

Studies had to include assessment of knee extensor muscle strength (i.e., peak torque, total work of repetitions, or as a leg symmetry index (LSI) in patients with no radiographic or symptomatic knee osteoarthritis at baseline), and they had to have a follow-up time of a minimum of 2 years. Radiographic or symptomatic knee osteoarthritis had to be assessed at the time of follow-up. Studies reporting self-reported physician diagnosed osteoarthritis were included. Studies that included patients with knee pain only, osteoarthritis in the patellofemoral joint only, or other rheumatologic diseases than osteoarthritis, were excluded.

Literature search and study selection

The systematic searches were carried out in Medline (PubMed), SPORTDiscus, EMBASE, CINAHL, and AMED in September 2013. The search strategy was adjusted to each database's specifications (see Appendix for detailed search strategies). No restrictions were set for the searches with respect to language or publication year. Reference lists of relevant articles were reviewed to identify additional studies that did not appear in the systematic searches. Abstracts of all identified articles were then read to decide inclusion or exclusion in the systematic review. When in doubt, full text articles were reviewed. Study eligibility was independently assessed by two of the authors (BEO and JBT). Disagreements were resolved by discussion until consensus was reached.

Data collection

The following data was extracted from the included studies: number of subjects, sex, age, body mass index (BMI), type of subgroups (e.g., knee injury or elderly people), follow-up years, definition of knee osteoarthritis, and knee extensor muscle strength. For the meta-analysis, odds ratios (ORs) for the association between knee extensor muscle strength and development of either symptomatic and/or radiographic knee osteoarthritis were extracted. In studies regarded as relevant, but with lack of adequate muscle strength data, or data comparing men and women, we contacted the corresponding authors for additional data. Hierarchies for definitions of knee osteoarthritis and knee extensor muscle weakness were decided prior to the data searches. The hierarchies were used for data extraction in cases where two or more measures of osteoarthritis and knee extensor muscle strength were used in the individual studies. The hierarchy for osteoarthritis was based upon current criteria for defining knee osteoarthritis. The American College of Rheumatology criteria[10] was used for defining symptomatic knee osteoarthritis, including definite osteophytes and knee pain, but other methods including radiographic atlases plus knee pain was also sufficient. Radiographic atlases (e.g., the Kellgren and Lawrence (K/L) classification $\geq$ 2) were used to define radiographic tibiofemoral and patellofemoral osteoarthritis. The hierarchy for osteoarthritis was defined as follows: (1) Symptomatic radiographic whole knee osteoarthritis (including tibiofemoral and patellofemoral joints); (2) Symptomatic radiographic tibiofemoral osteoarthritis; (3) Radiographic whole knee osteoarthritis; (4) Radiographic tibiofemoral osteoarthritis, and (5) Self-reported physician diagnosed osteoarthritis. The hierarchy for knee extensor muscle weakness was defined on the basis of the muscle strength units most commonly used in the orthopedic, as well as the rheumatologic literature, as no international recommendations or gold standard exist: (1) Knee extensor peak torque (Newton meter (Nm)) normalized to body weight (Nm/kilograms (kg)); (2) Knee extensor peak torque (Nm); (3) Knee extensor peak torque normalized to lower extremity muscle mass (Nm/kg lower extremity muscle mass), and (4) LSI (% of muscle strength between injured and uninjured knee), and (5) One repetition maximum leg-press.

Synthesis of results

Meta-analysis was applied on the basis of the OR of developing osteoarthritis in subjects with knee extensor muscle weakness. In studies with no presented ORs, the data was transformed to OR from standard mean difference of muscle strength between the group of participants who developed osteoarthritis and those who did not. Data from adjusted analyses were extracted if available. Random effect models were used, as large clinical heterogeneity was expected in the definitions of both knee extensor muscle weakness and knee osteoarthritis. Heterogeneity between trials was examined with standard *Q*-tests, and calculated as the I^2 statistics[11] measuring the proportion of inconsistency in the combined estimates due to between-study heterogeneity[12]. Stratified analyses were performed for men and women. Furthermore, we explored the impact of including radiographic knee osteoarthritis instead of symptomatic knee osteoarthritis for those studies including both outcomes, as well as excluding studies using self-reported osteoarthritis. We also conducted sensitivity analyses excluding the studies on anterior cruciate ligament (ACL) reconstructed subjects. Our initial intention was to conduct subgroup analyses on patients with previous knee injury (i.e., ACL injury), overweight, or malalignment. However, sufficient data for these analyses where not found, and thus not included in the present study.

Risk of bias

Study quality was assessed by two reviewers (BEO and JBT) using the guidelines from the Centre for Reviews and Dissemination (CRD) guidance on systematic reviews (CRD)[13], in addition to one item from the Down & Black checklist[14]. The following questions were answered: (1) Was there a sufficient description of the groups and the distribution of prognostic factors? (2) Were the prognostic factors accurately assessed? (3) Were the groups assembled at a similar point in their disease progression? (4) Were the groups comparable on all the important confounding factors? (5) Was there adequate adjustment for the effects of these confounding variables? (6) Was outcome assessment blind to exposure status? (7) Was follow-up long enough for the outcomes to occur? (8) Was a sufficient proportion of the cohort included at follow-up? (9) Were dropout rates and reasons for dropout similar across intervention and unexposed groups? (10) Was a dose−response relationship between intervention and outcome demonstrated? (11) Were the main outcome measures used accurately (valid and reliable)? Each of these key components of methodological quality was considered ‘Adequate’, ‘Unclear’, or ‘Inadequate’.

Results

Study selection

Through the primary searches, and before exclusion of duplicates, 165 hits appeared in Medline; 609 in EMBASE; 69 in SportsDiscus; 130 in CINAHL, and 27 in AMED. Twelve studies were considered for inclusion after reading the abstracts. Five of these were included in the final meta-analysis (Fig. 1)[4−6,15,16]. The seven

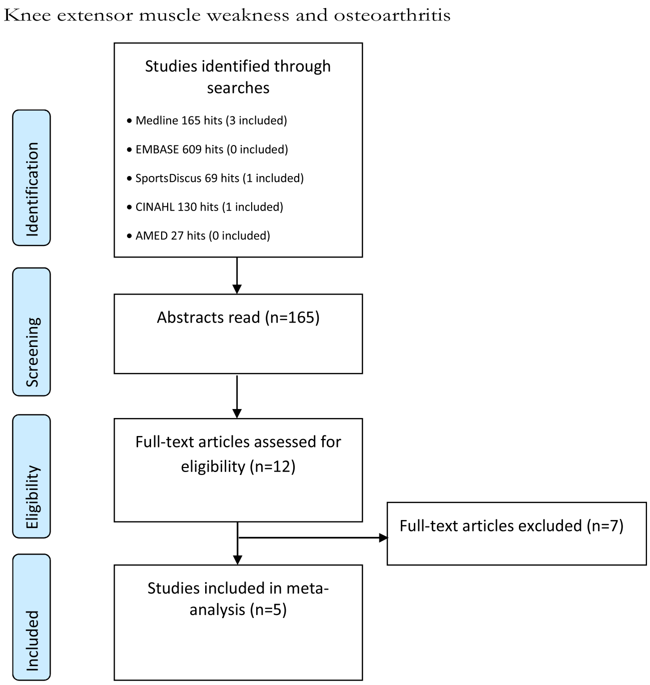

Fig. 1. Flow diagram of study selection.

studies that were excluded investigated progression of osteoarthritis[17,18]; did not report data for knee extensor muscle weakness related to the development of knee osteoarthritis[19]; did not measure knee extensor weakness objectively[20]; did not define osteoarthritis as outcome[21]; had a cross-sectional study design[22], or investigated the same study population as another included study[23]. Additional data was provided by Keays *et al.*[16] (unadjusted risk of developing radiographic osteoarthritis with weak knee extensor muscle strength in men and women), and Øiestad *et al.*[15] (age and BMI adjusted risk of developing radiographic or symptomatic osteoarthritis in men and women).

Study characteristics

The five cohort studies had a follow-up time between 2.5 and 14 years, and a total of 5707 study participants, including 3553 (62.3%) men and 2154 (37.7%) women (Table I). The study samples consisted of middle-aged people without knee injury[6], elderly people (>60 years) at risk of knee osteoarthritis (for instance overweight and/or knee injury)[5], elderly >70 years[4], and younger people with ACL reconstruction[15,16]. In two studies with adjusted analyses, knee extensor muscle weakness was defined as being in the lowest tertile of knee extensor muscle strength[5,6], in one study with adjusted analyses, knee extensor muscle weakness was defined as having an LSI of <80% compared to the non-ACL reconstructed knee 6 months after ACL reconstruction[15], and in two studies with unadjusted analyses, knee extensor muscle weakness was compared between those who did and those who did not develop osteoarthritis[4,16].

Synthesis of results and subgroup analysis

The primary analysis, including a combination of methods to define osteoarthritis (Table II), showed an increased risk of knee osteoarthritis in individuals with knee extensor muscle weakness (OR 1.65 95% confidence interval (CI) 1.23, 2.21; $I^2 = 50.5\%$) (Fig. 2). Stratified analyses for sex showed an increased risk in both men (OR 1.68 95% CI 1.10, 2.58; $I^2 = 55.5\%$) and women (OR 1.59 95% CI 0.94, 2.68; $I^2 = 54.3\%$). Differences in risk between men and women did not reach statistical significance ($P = 0.87$) (Fig. 2).

Sensitivity analysis replacing symptomatic osteoarthritis with radiographic osteoarthritis (possible in two studies) did not change the risk of knee osteoarthritis with knee extensor muscle weakness (OR 1.58 95% CI 1.12, 2.23) (Table II). This was also true when excluding the study using self-reported osteoarthritis[6] (OR 1.64, 95% CI 1.09, 2.48), and when excluding studies on ACL reconstructed subjects (OR 1.56, 95% CI 1.32, 1.85) (Table II). Information of osteoarthritis definitions and strength measures included in the different analysis are given in Table II.

Risk of bias

Study quality is presented in Table III. Description of the study groups and the distribution of prognostic factors, assessment of prognostic factors, and assessment at a similar point in disease progression were adequate for all the selected studies. None of the studies had adequately adjusted for all possible confounding factors, e.g., knee injuries.

Discussion

This meta-analysis, including five studies with more than 5700 patients, showed an increased risk of knee osteoarthritis after 2.5–14 follow-up years in a mixed population of individuals with baseline knee extensor muscle weakness. When stratified by sex, an increased risk was displayed in both men and women.

Previous reviews have suggested knee extensor muscle weakness to be a risk factor for developing knee osteoarthritis[7–9],

Table I
Characteristics of included studies

	No of subjects (% of study cohort)	Men/women	Age* (Sd)	BMI	No with incident OA (%)	Definition of OA	Definition of knee extensor weakness†	Follow-up years
Hootman *et al.*[6]	3081 (55%)	2422/659	46.9 (9.5)	25.3 (3.8)	222/3081 (7.2)	Self-reported knee or hip OA	PT (kg/m)/BW	14.4 years
Segal *et al.*[5]	2078 (69%)	846/1232	62.3 (8.0)	30.2 (5.5)	310/3392 (9.1)‡	Symptomatic radiographic whole knee OA	PT (Nm)	2.5 years
Slemenda *et al.*[4]	342 (74%)	164/178	70.8 (4.6)	n.a	31/342 (9.1)	Radiographic OA	Lb-ft/BW	2.5 years
Øiestad *et al.*[15]	164 (82%)	93/71	27.4 (8.5)	26.3 (3.8)	58/164 (35.4)	Symptomatic radiographic knee OA	TW (Nm)	12.1 years
Keays *et al.*[16]	42 (75%)	28/14	27.4 (5.5)	n.a	20 subjects (47.6)	Radiographic knee OA	PT (Nm)	6 years

No, number; Sd, standard deviation; OA, osteoarthritis; PT, peak torque; kg, kilograms; m, meter; BW, body weight; Nm, Newton meter; n.a., not available; Lb-ft, pound-foot (torque); TW, total work of five repetitions.
* Mean age at baseline.
† All studies tested knee extensor strength using isokinetic equipment.
‡ Reported as number of knees.

Table II
Overview of definitions of osteoarthritis used in the different analyses

	Definition of osteoarthritis	OR (95% CI)	I^2
Primary analysis:		1.65 (1.23; 2.21)	50.5%
Slemenda *et al.*[4]	Radiographic knee osteoarthritis		
Hootman *et al.*[6]	Self-reported knee or hip osteoarthritis		
Segal *et al.*[5]	Symptomatic radiographic whole knee osteoarthritis		
Øiestad *et al.*[15]	Symptomatic radiographic knee osteoarthritis		
Keays *et al.*[16]	Radiographic knee osteoarthritis		
Sensitivity analysis 1*:		1.58 (1.12; 2.23)	56.0%
Slemenda *et al.*[4]	Radiographic knee osteoarthritis		
Segal *et al.*[5]	Radiographic knee osteoarthritis		
Øiestad *et al.*[15]	Radiographic knee osteoarthritis		
Keays *et al.*[16]	Radiographic knee osteoarthritis		
Hootman *et al.*[6]	Self-reported knee or hip osteoarthritis		
Sensitivity analysis 2†:		1.64 (1.09, 2.48)	51.5%
Slemenda *et al.*[4]	Radiographic knee osteoarthritis		
Segal *et al.*[5]	Symptomatic radiographic whole knee osteoarthritis		
Øiestad *et al.*[15]	Symptomatic radiographic knee osteoarthritis		
Keays *et al.*[16]	Radiographic knee osteoarthritis		
Sensitivity analysis 3‡:		1.56 (1.32, 1.85)	0.0%
Slemenda *et al.*[4]	Radiographic knee osteoarthritis		
Hootman *et al.*[6]	Self-reported knee or hip osteoarthritis		
Segal *et al.*[5]	Symptomatic knee osteoarthritis		

I, inconsistency between studies.
* Analysis replacing symptomatic osteoarthritis with radiographic osteoarthritis where possible (i.e., Segal *et al.* and Øiestad *et al.*).
† Primary analysis, but with exclusion of study using self-reported knee or hip osteoarthritis (Hootman *et al.*).
‡ Primary analysis, but excluding the two studies including ACL reconstructed subjects (Øiestad *et al.* and Keays *et al.*).

however, without synthesizing the results in a meta-analysis. Segal and Glass[7] concluded that greater quadriceps muscle strength protected against incident symptomatic, but not radiographic knee osteoarthritis in men and women. We found knee extensor muscle weakness at baseline to be a risk factor for later knee osteoarthritis; assessed as a combination of symptomatic whole knee osteoarthritis, radiographic knee osteoarthritis, and self-reported osteoarthritis for both men and women. Following sensitivity analyses, we found our results to be robust both when replacing symptomatic osteoarthritis with radiographic osteoarthritis, when excluding the study with self-reported osteoarthritis, and when excluding the studies with ACL reconstructed subjects. This meta-analysis included heterogeneous populations, ranging from younger subjects with knee injury, to middle-aged persons with no previous knee injuries[6], overweight individuals[5], and elderly people[4]. Still, the results in the different studies are compatible, both in men and women, supporting that knee extensor muscle weakness is a general risk factor for knee osteoarthritis across populations (Fig. 2).

The definition of knee osteoarthritis is diverse in research studies; as it may be derived either on the basis of symptomatic findings and/or on radiographic findings. As we expected a small number of eligible studies, accompanied by discrepancies in the definitions of knee osteoarthritis, we predefined a hierarchy for knee osteoarthritis outcomes prior to data extraction. As pain is regarded a cardinal symptom of knee osteoarthritis[24], symptomatic definitions were ranked higher than definitions based solely on radiographic findings. Self-reported physician diagnosed osteoarthritis was considered the least valid outcome.

The role of knee extensor muscles weakness as a risk factor for development of knee osteoarthritis is not fully understood. The knee extensors work as shock absorbers and stabilizers, and hence protect the joint surfaces during loading and movement[8]. Excessive mechanical stress on articular cartilage due to muscle weakness has been suggested to induce a degenerative process[25,26]. However, it still remains to be proven if knee extensor muscle strengthening can reduce the onset or progression of knee osteoarthritis. Mikesky *et al.*[19] found no association between muscle strength and incident joint space narrowing in people following participation in a 3-months exercise program. The participants in fact lost muscle strength during the intervention period, probably due to low adherence and inadequate compliance to the exercise program. In addition, Bennell *et al.*[27] reported no change in the external knee adduction moment (a surrogate measure of medial compartment knee joint loading) after a 12-week quadriceps strength program in patients with moderate to severe knee osteoarthritis, although reduced pain was observed. On the basis of the current literature, it seems difficult to induce altered loading patterns from muscle strengthening exercises, but due to the beneficial effects on pain and function, muscle strengthening exercises are nevertheless recommended[28]. Even though isokinetic knee extensor muscle strength was assessed in all the included studies, the reporting of measurement units was divergent in part because of utilization of different methods to account for body size. At present state, there is no recommended international gold standard for either the selection of outcome measures or the method of normalization when reporting muscle strength assessments. The most common method within the orthopedic and rheumatologic literature on people with acute knee injuries or knee osteoarthritis has been normalization on the basis of body mass or BMI. Unfortunately, we were only able to include muscle strength data normalized to body weight or BMI. Allometric scaling (e.g., normalized strength $=$ strength/mass^q, where q $=$ allometric parameter), has been suggested as a better normalization method than those solely based on body mass or BMI[29]. The numbers with incident knee osteoarthritis ranged from 7 to 47 percent across the studies, with the highest incidence numbers in the two ACL studies. These two studies included relatively few participants, and the study by Keays *et al.* showed a large CI. Excluding these studies did not change the risk of developing knee osteoarthritis with weak knee extensor strength.

The risk of bias, as detected by the criteria from the CRD guidance on systematic reviews, revealed methodological weaknesses for adjustment for confounding factors. It is difficult to isolate the relationship between knee extensor muscle weakness and development of knee osteoarthritis from potential confounding factors such as age, sex, and BMI. Thus, such variables should always be included in analyses on the relationship between knee extensor muscle weakness and the risk of knee osteoarthritis, but were accounted for in only three of the included studies. Segal *et al.*[5] in addition accounted for hip bone density, surgical history (but not injuries), knee pain, and self-reported physical activity score which was a strength of this study. Joint injuries, including ACL and meniscus injuries, are important factors that may influence the relationship between knee extensor muscle weakness and knee osteoarthritis, as knee injuries are among the strongest risk factors for the development of knee osteoarthritis[30,31].

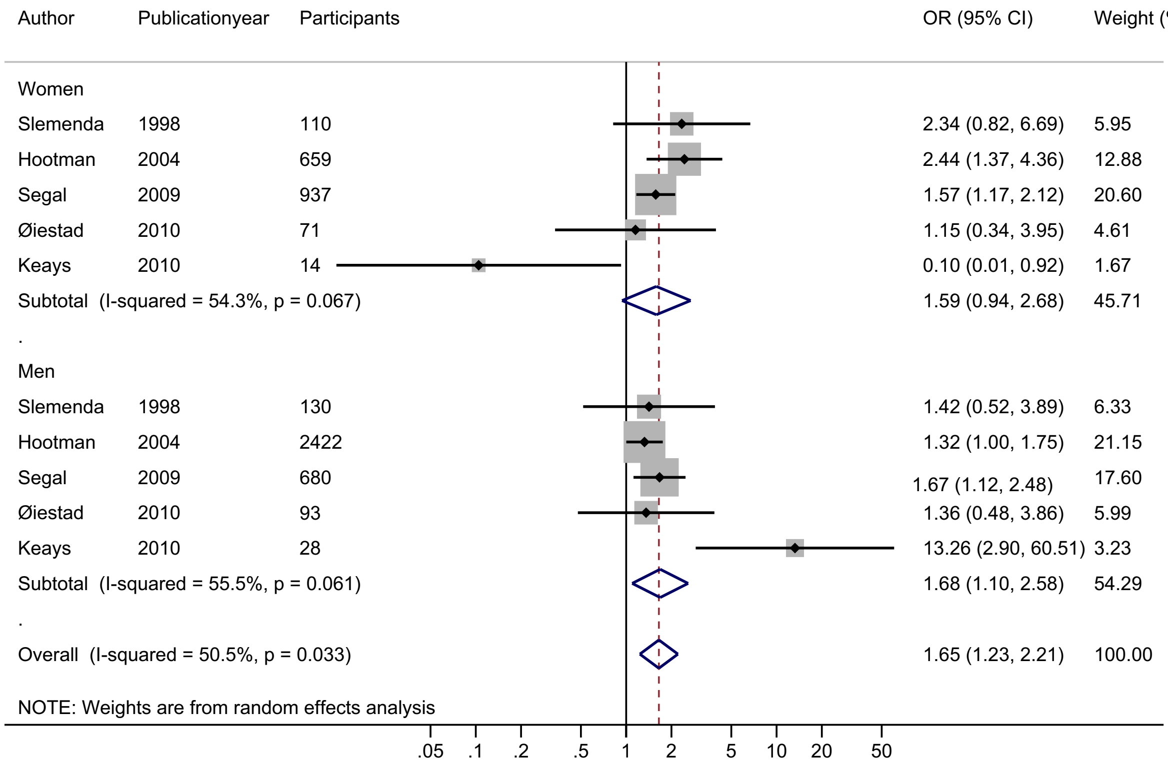

Fig. 2. Results of meta-analyses on knee extensor muscle weakness and the risk of knee osteoarthritis.

Table III
Risk of bias

Criteria	Hootman[6]	Keays[16]	Segal[5]	Slemenda[4]	Øiestad[15]
Where there sufficient description of prognostic factors?	A	A	A	A	A
Were the prognostic factors accurately assessed?	A	A	A	A	A
Were the groups assembled at a similar point in disease progression?	A	A	A	A	A
Were the groups comparable on all important confounding factors?	U	U	U	U	U
Was there adequate adjustment for the effects of these confounding factors?	A	I	A	I	A
Was outcome assessment blind to exposure status?	A	A	A	A	A
Was follow-up long enough for the outcomes to occur?	A	A	A	A	A
Was a sufficient proportion of the cohort followed up?	U	I	A	A	A
Were dropout rates and reasons for dropout similar across intervention and unexposed groups?	U	I	U	U	A
Was a dose–response relationship between intervention and outcome demonstrated?	U	U	U	U	U
Was the main outcome measure used accurate (valid and reliable)?	A	A	A	A	A

A, adequate; U, unclear; I, inadequate.

This is the first meta-analysis on the relationship between knee extensor muscle weakness and risk of knee osteoarthritis, and the results revealed significant relationships in both men and women. However, some study weaknesses have to be addressed. One researcher only performed the initial study selection, and we were not able to get additional data from one of the studies as requested[19]. Only five studies were included in the meta-analysis. Although the studies were all prospective cohort studies, different study populations were included, and different methods were utilized to define knee osteoarthritis. In addition, the study by Hootman *et al.* included subjects with self-reported knee *or hip* osteoarthritis, and did not report the number of people with knee osteoarthritis separately. We were not able to conduct subgroup analyses other than for sex, due to the limited data. Finally, even though the included studies were prospective cohort studies, methodological weaknesses were revealed through the assessment of the studies (Table III). Observational studies are preferred for assessing risk factors, however, the risk of bias in such studies is always a threat to the validity of the results[32]. The inconsistency between studies was moderate ($I^2 = 50.5\%$), however, this was mainly due to the small study by Keays *et al.* as no inconsistency was seen when excluding this study from the primary analysis ($I^2 = 0.0\%$) (data not shown). Thus, the data support that knee extensor muscle weakness is a general risk factor across populations.

Conclusion

This systematic review and meta-analysis showed that knee extensor muscle weakness was associated with an increased risk of developing knee osteoarthritis during 2.5–14 year follow-up in both men and women.

Contributions

Britt Elin Øiestad takes responsibility for the integrity of the work as a whole, from inception to finished article.

Carsten Juhl contributed with acquisition of data, analysis and interpretation of data, revising the manuscript critically for important intellectual content, and approved the version to be submitted.

Ingrid Eitzen contributed with analysis and interpretation of data, revising the manuscript critically for important intellectual content, and approved the version to be submitted.

Jonas Thorlund contributed to design of the study, analysis and interpretation of data, drafting the article, and gave final approval of the version to be submitted.

Competing of interest

No conflicts of interest were declared.

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Appendix

MEDLINE

('risk factors'[MeSH Terms] OR 'risk factors'[TIAB] OR 'risk'[-MeSH Terms] OR 'risk'[TIAB] OR 'causality'[MeSH Terms] OR "causal*'[TIAB] OR 'prognos*'[TIAB] OR 'Causation'[TIAB] OR (("Reinforcing'[TIAB] OR 'Enabling'[TIAB] OR 'predisposing'[TIAB]) AND ('factor'[TIAB] OR 'factors'[TIAB]))) AND ('Arthrosis*'[TIAB] OR 'Degenerative arthritis'[TIAB] OR 'Osteoarthr*'[TIAB] OR 'Osteoarthritis'[MeSH] OR 'Degenerative Arthritides'[TIAB] OR 'Osteoarthrosis Deformans'[TIAB]) AND ('Knee'[MeSH]OR 'Knee*'[TIAB] OR 'Knee Joint'[MeSH] OR 'Knee Joint'[TIAB]) AND ('Muscle strength*'[TIAB] OR 'Muscle strength'[MeSH] OR 'Muscle weakness'[TIAB] OR 'lower extremity strength'[TIAB] OR 'quadriceps strength' [TIAB] OR 'knee extensor strength'[TIAB] OR 'leg-muscle strength'[TIAB] OR 'muscle power'[TIAB] OR 'muscle performance'[TIAB] OR 'knee strength'[TIAB] OR 'muscle function'[TIAB] OR 'quadriceps deficit'[TIAB] OR 'quadriceps force'[TIAB] OR 'quadriceps weakness'[TIAB] OR 'knee extension strength'[TIAB] OR 'leg press power'[TIAB] OR 'lower limb strength'[TIAB] OR 'knee power'[TIAB] OR 'knee instability'[TIAB] OR 'quadriceps femoris strength'[TIAB] OR 'quadriceps femoris muscle(s)'[TIAB]).

EMBASE

('risk factors'/syn OR 'risk'/syn OR 'causality'/syn OR causal* OR prognos* OR causation OR (reinforcing OR enabling OR predisposing AND (factor OR factors))) AND (arthrosis* OR 'degenerative arthritis'/syn OR osteoarthr* OR 'osteoarthritis'/syn OR 'degenerative arthritides' OR 'osteoarthrosis deformans') AND ('knee'/syn OR knee* OR 'knee joint'/syn) AND ('muscle'/syn AND strength* OR 'muscle strength'/syn OR 'muscle weakness'/syn OR 'lower extremity strength' OR 'quadriceps strength' OR 'knee extensor strength' OR 'leg-muscle strength' OR 'muscle power'/syn OR 'muscle performance'/syn OR 'knee strength' OR 'muscle function'/syn OR 'quadriceps deficit' OR 'quadriceps force' OR 'quadriceps weakness' OR 'knee extension strength' OR 'leg press power' OR 'lower limb strength' OR 'knee power' OR 'knee instability'/syn OR 'quadriceps femoris strength' OR 'quadriceps femoris muscle(s)').

SPORTDISCUS

(risk OR 'risk factors' OR causality OR cau* OR prognos* OR causation OR (reinforcing OR enabling OR predisposing AND (factor OR factors))) AND (arthrosis* OR 'degenerative arthritis' OR osteoarthr* OR osteoarthritis OR 'degenerative arthritises' OR 'osteoarthritis deforms') AND (knee OR knee* OR 'knee joint') AND muscle AND (strength OR 'muscle strength' OR 'muscle weakness' OR 'lower extremity strength' OR 'quadriceps strength' OR 'knee extensor strength' OR 'leg-muscle strength' OR 'muscle power' OR 'muscle performance' OR 'knee strength' OR 'muscle function' OR 'quadriceps deficit' OR 'quadriceps force' OR 'quadriceps weakness' OR 'knee extension strength' OR 'leg press power' OR 'lower limb strength' OR 'knee power' OR 'knee instability' OR 'quadriceps memories strength' OR 'quadriceps memories muscle').

CINAHL

(risk OR 'risk factors' OR causality OR cau* OR prognos* OR causation OR (reinforcing OR enabling OR predisposing AND (factor OR factors))) AND (arthrosis* OR 'degenerative arthritis' OR osteoarthr* OR osteoarthritis OR 'degenerative arthritises' OR 'osteoarthritis deforms') AND (knee OR knee* OR 'knee joint') AND muscle AND (strength OR 'muscle strength' OR 'muscle weakness' OR 'lower extremity strength' OR 'quadriceps strength' OR 'knee extensor strength' OR 'leg-muscle strength' OR 'muscle power' OR 'muscle performance' OR 'knee strength' OR 'muscle function' OR 'quadriceps deficit' OR 'quadriceps force' OR 'quadriceps weakness' OR 'knee extension strength' OR 'leg press power' OR 'lower limb strength' OR 'knee power' OR 'knee instability' OR 'quadriceps memories strength' OR 'quadriceps memories muscle').

AMED

(risk OR 'risk factors' OR causality OR cau* OR prognos* OR causation OR (reinforcing OR enabling OR predisposing AND (factor OR factors))) AND (arthrosis* OR 'degenerative arthritis' OR osteoarthr* OR osteoarthritis OR 'degenerative arthritises' OR 'osteoarthritis deforms') AND (knee OR knee* OR 'knee joint') AND muscle AND (strength OR 'muscle strength' OR 'muscle weakness' OR 'lower extremity strength' OR 'quadriceps strength' OR 'knee extensor strength' OR 'leg-muscle strength' OR 'muscle power' OR 'muscle performance' OR 'knee strength' OR 'muscle function' OR 'quadriceps deficit' OR 'quadriceps force' OR 'quadriceps weakness' OR 'knee extension strength' OR 'leg press power' OR 'lower limb strength' OR 'knee power' OR 'knee instability' OR 'quadriceps memories strength' OR 'quadriceps memories muscle').

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