

SYSTEMATIC REVIEW

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Influence of diabetes on the risk of deep vein thrombosis of patients after total knee arthroplasty: a meta-analysis

Jingzhi An¹, Li Han¹, Xiaojuan Ma^{1,2}, Yanyan Chang¹ and Cuixin Zhang^{1*}

Abstract

Background Previous studies evaluating the influence of diabetes on the risk of deep vein thrombosis (DVT) after total knee arthroplasty (TKA) showed inconsistent results. The aim of the study was to systematically evaluate the association between diabetes and DVT after TKA in a meta-analysis.

Methods An extensive search was conducted in PubMed, Embase, and Web of Science to identify relevant cohort studies. Random-effects models were employed to pool the results after taking account of the potential influence of heterogeneity.

Results Thirteen cohort studies involving 546,156 patients receiving TKA were included, with 71,110 (13.0%) diabetic patients before surgery and 1479 (2.1%) patients diagnosed as DVT after surgery. Overall, diabetes was associated with an increased risk of DVT after TKA (risk ratio [RR]: 1.43, 95% confidence interval [CI]: 1.12–1.84, $p=0.004$; $I^2=44\%$). Sensitivity analysis limited to studies with chemoprophylaxis (RR: 1.96, 95% CI: 1.50–2.54), and studies with multivariate analysis (RR: 1.54, 95% CI: 1.12–2.11) showed consistent results. Subgroup analysis showed that diabetes was associated with higher risk of postoperative DVT in Asian countries (RR: 1.93, 95% CI: 1.49–2.52, $p<0.001$; $I^2=1\%$) but not in Western countries (RR: 1.07, 95% CI: 0.86–1.34, $p=0.52$; $I^2=0\%$; p for subgroup difference <0.001).

Conclusion Diabetes may be a risk factor for DVT after TKA, even with the chemoprophylaxis of anticoagulants. The association between diabetes and DVT after TKA may be more remarkable in patients from Asian countries.

Keywords Total knee arthroplasty, Deep vein thrombosis, Diabetes, Risk factor, Meta-analysis

Introduction

Diabetes is a common metabolic disorder characterized by hyperglycemia resulted from insufficient pancreatic islet β cell function and insulin resistance [1]. With the aging of the globe population, the prevalence of diabetes is expected to continuously increase in the future decades

[2, 3]. Patients with diabetes are shown to be associated with higher risks of cardiovascular complications [4]. Moreover, increasing evidence suggests that for patients undergoing surgical procedures, diabetes may also be associated with poor postoperative outcomes [5, 6].

Total knee arthroplasty (TKA) is a frequently performed orthopedic surgery primarily for the treatment of severe knee joint diseases [7, 8]. Also due to the aging of the global population, TKA is increasingly performed in the recent years and patients receiving TKA are also expected to continuously grow in the future decades [9]. Deep vein thrombosis (DVT) is one of the common and severe postoperative complications in patients receiving TKA [10]. Clinically, DVT may cause pulmonary

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embolism, leading to increased morbidity and mortality in these patients [11, 12]. Therefore, identification of risk factors for DVT after TKA is important for early identification of high-risk patients. It is reported that up to 50% of patients receiving TKA may have diabetes before the surgery [13]. Some previous studies suggested that diabetes may be a risk factor for DVT after TKA [14–16], while a few other studies did not show the same results [17–21]. In view of this inconsistency, we performed a systematic review and meta-analysis to comprehensively evaluate the association between diabetes and DVT after TKA. In recent years, continuously efforts have been made for preventing DVT after TKA, such as use of chemoprophylaxis anticoagulants [22, 23]. Specifically, we aimed to evaluate if the potential association between diabetes and DVT after TKA remains even with the chemoprophylaxis of anticoagulants.

Materials and methods

The research followed the Meta-analyses Of Observational Studies in Epidemiology (MOOSE) guideline [24] and the Cochrane Handbook [25] consistently during the phase of planning, execution, and documentation.

Inclusion and exclusion criteria of studies

The development of inclusion criteria adhered to the PICOS recommendations and aligned with the objective of the meta-analysis.

P (patients): Adult patients (18 years or older) undergoing TKA.

I (exposure): Diabetes (type 1 or type 2 diabetes) was diagnosed and considered as the exposure before surgery.

C (control): Patients without the diagnosis of diabetes before surgery were considered as control.

O (outcomes): The primary outcome of the meta-analysis was the incidence of DVT after TKA, compared between patients with diabetes and normoglycemia.

S (study design): Cohort studies, including prospective and retrospective cohorts.

Excluded from the meta-analysis were literature reviews, editorials, meta-analyses, and studies that include patients not undergoing TKA, did not evaluate diabetes as exposure, or did not report the outcomes of interest. In instances where there was a duplication of patient populations, the study with the most extensive sample size was incorporated into the meta-analysis.

Search of databases

Studies relevant to the objective of the meta-analysis were identified by search of electronic databases, namely PubMed, Embase, and Web of Science encompassing the period from inception to November 10, 2023. The search strategy employed relevant terms pertaining to

the subject matter of our investigation, aiming to identify studies published within this timeframe, which included: (1) "diabetes" OR "diabetic"; (2) "total knee replacement" OR "total knee arthroplasty"; and (3) "deep vein thrombosis" OR "DVT." Only studies that met the criteria of being published as full-length articles in English and appearing in peer-reviewed journals were included in our analysis. Additionally, during our manual screening process, we thoroughly examined the references cited in relevant original and review articles to identify any potentially relevant studies.

Data extraction and quality evaluation

Two authors conducted literature searches, collected data, and assessed the quality of the studies separately. In instances where inconsistencies arose, the authors engaged in discussions to reach a consensus. The analysis of the studies involved gathering data pertaining to study details, design attributes, sample size, patient demographics, definition of diabetes, number of patients with diabetes before surgery, follow-up duration, methods for DVT prevention, methods for detection of DVT after TKA, number of patients who developed DVT after TKA, and variables adjusted when the association between diabetes and postoperative DVT was reported. The quality of the study was evaluated using the Newcastle–Ottawa Scale (NOS) [26]. This scale assesses the quality of cohort studies based on three dimensions: the selection of study groups, the comparability of these groups, and the ascertainment of the outcome of interest. The NOS varied between one and nine stars, with a higher star indicating a better study quality.

Statistics

Odds ratio (ORs) and their corresponding 95% confidence intervals (CIs) were utilized as the variables to assess the relationship between diabetes and the risk of DVT after TKA. In order to stabilize and standardize the variance, a logarithmic transformation was implemented on the OR and its corresponding standard error in each study [27]. The Cochrane Q test and the I^2 statistic [28] were utilized to assess between-study heterogeneity. A value of I^2 exceeding 50% signifies the existence of substantial heterogeneity among the studies. The random-effects model was employed for synthesizing the results, as it is acknowledged for its ability to accommodate potential heterogeneity [25]. A sensitivity analysis by excluding one study at a time was performed to evaluate the robustness of the findings [25]. Moreover, sensitivity analyses limiting to studies with the use of chemoprophylaxis for DVT and to studies with multivariate analyses only were also performed. In addition, subgroup analyses according to the study country (Asian or Western)

and NOS were also performed. Publication bias was estimated using a funnel plot, which involved visual assessments of symmetry, as well as Egger’s regression asymmetry test [29]. The statistical analyses were conducted using RevMan (version 5.1; Cochrane Collaboration, Oxford, UK) and Stata software (version 12.0; Stata Corporation, College Station, TX).

Results

Database search and study retrieval

Figure 1 illustrates the procedure employed for conducting the literature search and study retrieval. Initially, a total of 392 records were acquired from the designated database, and subsequently, 109 duplicate entries were eliminated. Upon scrutinizing the titles and abstracts,

an additional 256 studies were excluded due to their incompatibility with the objectives of the meta-analysis. Following comprehensive evaluations of the full texts of 27 studies, 14 were excluded based on the rationales outlined in Fig. 1. Consequently, thirteen studies [14–21, 30–34] were deemed suitable for the subsequent meta-analysis.

Study characteristics

Overall, 13 retrospective cohort studies [14–21, 30–34] were included in the meta-analysis. The characteristics of the studies and the included patients are shown in Table 1. These studies were published between 2003 and 2023 and performed in the USA, Spain, China, and Korea. Overall, 546,156 patients receiving TKA

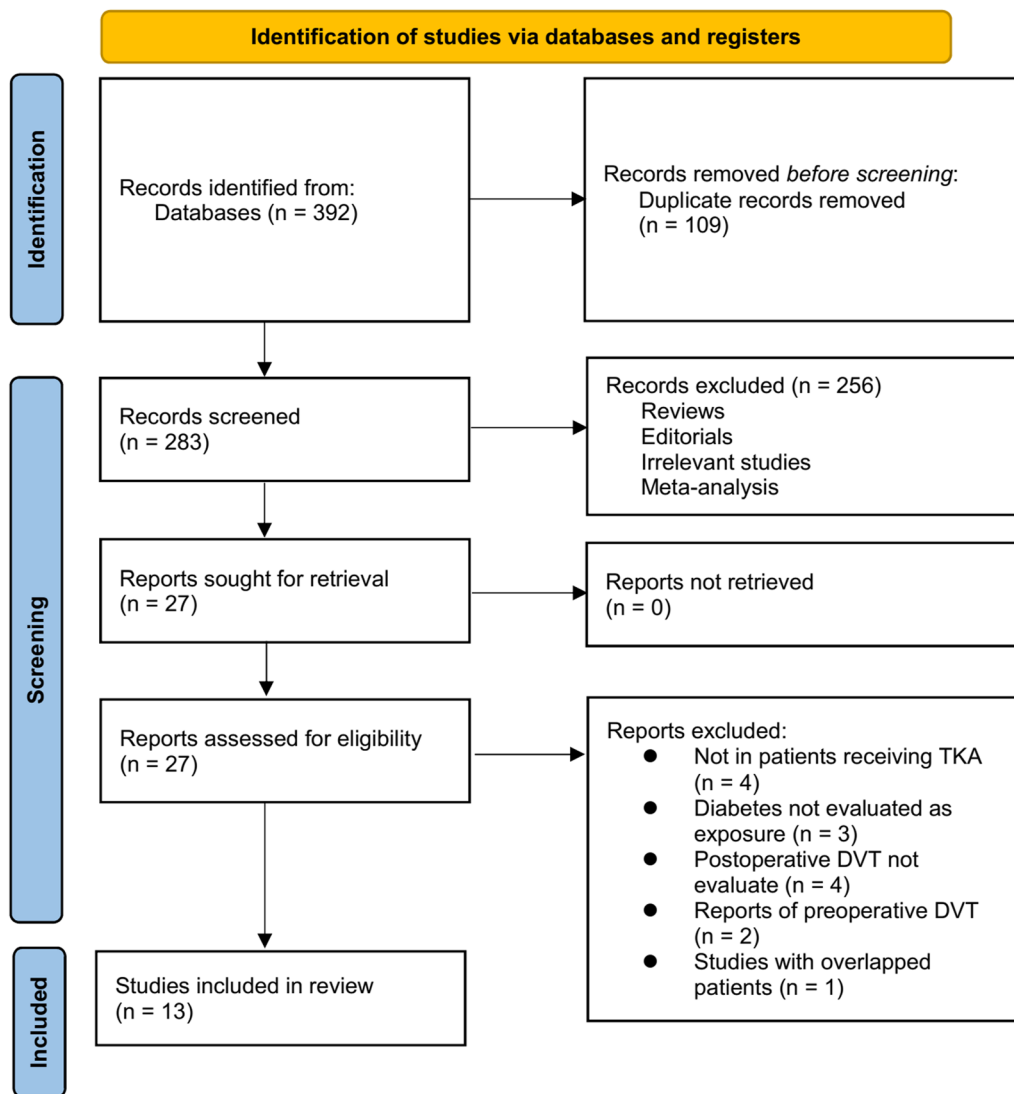


Fig. 1 Flowchart of database search and study inclusion;

Table 1 Characteristics of the included studies

Study	Country	Design	Number of patients	Mean age (years)	Men (%)	Definition of DM	Number of patients with DM	Follow-up duration	Methods for DVT prevention	Methods for confirmation of postoperative DVT	Number of patients with postoperative DVT	Variables adjusted
Meding 2003	US	RC	3519	70	40.7	T1D or T2D	291	During hospitalization	IV heparin during surgery	Clinically screened with DUS for all the patients	13	Age and sex
Bolognesi 2008	US	RC	458,986	67.9	38.8	T1D or T2D	46,315	During hospitalization	NR	ICD codes	225	Age, race, sex, and income
Moon 2008	Korea	RC	342	67.5	9.4	T1D or T2D	171	During hospitalization	Not performed	Clinically screened with DUS for all the patients	5	Age, sex, and BMI
Wang 2013	China	RC	245	67	29.4	T1D or T2D	53	14 days	LMWH for 14 days starting on the first postoperative day	Clinically screened with DUS for all the patients	125	Age, sex, type of anesthesia, hypertension, and CAD
Adams 2013	US	RC	40,491	68	37.5	T1D or T2D	7567	90 days	NR	Clinically screened with DUS for all the patients	200	Age, sex, BMI, and CCI
Zhao 2014	China	RC	358	68	33.5	T1D or T2D	70	14 days	LMWH for 14 days starting on the first postoperative day	Clinically screened with DUS for all the patients	198	Age, sex, and hypertension
Kang 2015	China	RC	1025	76.8	36.7	T1D or T2D	260	During hospitalization	LMWH postoperative	Clinically screened with DUS for all the patients	175	Age, sex, BMI, serum Hcy, FBG, surgery time, and use of foot pump
Song 2016	China	RC	109	66.8	18.3	T1D or T2D	14	During hospitalization	Rivaroxaban or LMWH postoperative	Clinically diagnosed with lower limb venography	26	None
Martinez 2017	Spain	RC	26,640	71.6	32.3	T2DM	13,320	During hospitalization	NR	ICD codes	67	Age, sex, and comorbidities

Table 1 (continued)

Study	Country	Design	Number of patients	Mean age (years)	Men (%)	Definition of DM	Number of patients with DM	Follow-up duration	Methods for DVT prevention	Methods for confirmation of postoperative DVT	Number of patients with postoperative DVT	Variables adjusted
Dai 2020	China	RC	431	67.9	19	T1D or T2D	70	During hospitalization	LMWH postoperative	Clinically screened with DUS for all the patients	95	None
Gu 2020	US	RC	13,246	NR	40.1	T1D or T2D	2865	30 days	NR	Clinically screened with DUS for all the patients	121	None
Lee 2021	Korea	RC	103	NR	11	T1D or T2D	23	During hospitalization	LMWH postoperative	Clinically diagnosed with lower limb venography	22	Age, sex, type of anesthesia, and BMI
Gao 2023	China	RC	661	69.8	32.5	T1D or T2D	91	During hospitalization	LMWH postoperative	Clinically diagnosed with lower limb venography	207	Age, sex, BMI, smoking, comorbidities, surgery time, and type of anesthesia

DM diabetes mellitus; DVT deep vein thrombosis; RC retrospective cohort; T1D type 1 diabetes; T2D type 2 diabetes; NR not reported; LMWH low molecular weight heparin; DUS Doppler ultrasonography; ICD International Classification of Disease; CAD coronary artery disease; BMI body mass index; Hcy homocysteine; FBG fasting blood glucose; CCI Charlson comorbidity index

were included. The mean ages of the patients were 66 to 77 years, and the proportions of men were 9% to 41%. All of the included studies observed the influence of diabetes on postoperative DVT except for one study [33], which investigated the influence of type 2 diabetes (T2D) only. Accordingly, 71,110 (13.0%) patients were with diabetes before surgery. The follow-up durations varied from during hospitalization to 90 days after surgery. Chemoprophylaxis for DVT with anticoagulants including heparin, low molecular weight heparin, or rivaroxaban was reported in eight studies [14–17, 20, 31, 32, 34], not used in one study [18], and not reported in another four studies [19, 21, 30, 33]. Confirmation of postoperative DVT was performed with clinical screening via Doppler ultrasonography or lower limb venography in 11 studies [14–21, 31, 32, 34] and evidenced by the International Classification of Disease codes in two studies [30, 33]. Accordingly, 1479 (2.1%) patients were diagnosed as DVT after surgery. Multivariate analyses were performed in ten studies when the association between diabetes and DVT after TKA was estimated [14–19, 30, 31, 33, 34], which adjusted the potential confounding factors such as age, sex, body mass index, and comorbidities. In the other three studies [20, 21, 32], univariate analyses were performed. The NOS of these studies ranged from six to nine, indicating moderate to good study quality (Table 2).

Meta-analysis results

Pooled results with 13 studies showed that overall, diabetes was associated with an increased risk of DVT after TKA (RR: 1.43, 95% CI: 1.12–1.84, $p=0.004$; Fig. 2A) with moderate heterogeneity ($I^2=44%$). Sensitivity analyses by excluding one study at a time showed similar results (data not shown). In addition, sensitivity analysis limited to studies with chemoprophylaxis for DVT (RR: 1.96, 95% CI: 1.50–2.54, $p<0.001$; $I^2=0%$; Fig. 2B) and studies with multivariate analysis (RR: 1.54, 95% CI: 1.12–2.11; $p=0.008$; $I^2=53%$; Fig. 2C) also showed consistent results. For most of the included studies, study country rather than the ethnicity of the patients was reported. Accordingly, we have performed subgroup analysis according to the country of the study (Asian countries versus western countries), which may somewhat reflect the influence of patient ethnicity on the outcome. It was shown that that diabetes was associated with higher risk of postoperative DVT in Asian countries (RR: 1.93, 95% CI: 1.49–2.52, $p<0.001$; $I^2=1%$) but not in Western countries (RR: 1.07, 95% CI: 0.86–1.34, $p=0.52$; $I^2=0%$; p for subgroup difference <0.001 ; Fig. 3A). Subgroup analysis according to NOS showed similar results (p for subgroup difference $=0.41$; Fig. 3B).

Publication bias

The funnel plots depicting the meta-analyses of the association between diabetes and DVT after TKA are shown in Fig. 4. Upon visual inspection, the plots exhibit symmetrical patterns, indicating a minimal presence of publication bias. The Egger's regression test also suggested a low risk of publication bias ($p=0.42$).

Discussion

This meta-analysis synthesized the results of 13 available cohort studies, and the results showed that compared to patients with normoglycemia, patients with diabetes before the surgery had a higher incidence of DVT after TKA. Further sensitivity analyses showed consistent results in patients with chemoprophylaxis for DVT and in studies with multivariate analyses after adjustment of potential confounding factors. Moreover, subgroup analysis suggested that diabetes was associated with a higher risk of DVT after TKA in studies from Asian countries, but not in those from western countries. Taken together, results of the meta-analysis indicate that diabetes may be a risk factor for DVT after TKA, even with the chemoprophylaxis of anticoagulants. The association between diabetes and DVT after TKA may be more remarkable in patients from Asian countries.

To the best of our knowledge, two previous meta-analyses have evaluated the influence of diabetes on DVT after TKA. One early meta-analysis published in 2014 included six available studies and showed that diabetes may increase the risk of DVT after TKA. Another meta-analysis published in 2015 included the same studies, which also retrieved similar results. However, significant heterogeneity was observed among these meta-analyses. Due to the limited number of available datasets, the authors did not perform further analyses to identify the source of heterogeneity. Moreover, chemoprophylaxis with anticoagulants has been suggested to be effective in reducing the risk of DVT after TKA [35]. However, none of the meta-analyses observed the potential influence of chemoprophylaxis on the association. In our meta-analysis, an extensive literature search was performed in three commonly used electronic databases, which retrieved 13 up-to-date cohort studies according to the aim of the meta-analysis. Only cohort studies were considered in this meta-analysis, thereby providing a longitudinal relationship between prediabetes and postoperative DVT. Subsequent sensitivity meta-analysis by omitting one study at a time showed consistent results, further reflecting the robustness of the finding. More important, sensitivity analysis limited to studies with the use of chemoprophylaxis for DVT showed consistent results, which support an association between diabetes

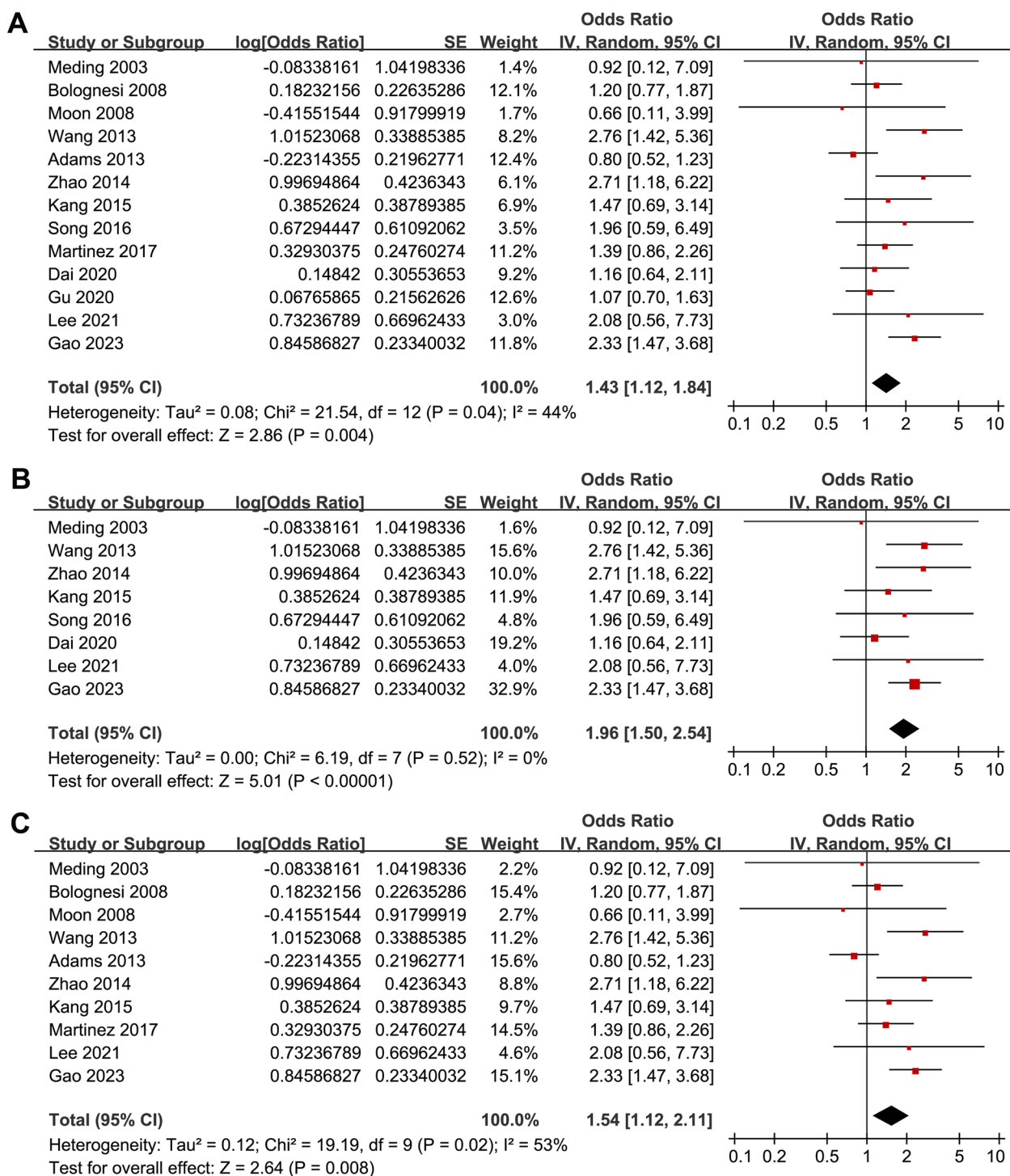


Fig. 2 Forest plots for the meta-analysis regarding the association between diabetes and DVT after TKA; A, forest plots for the overall meta-analysis; B, forest plots for the sensitivity analysis limited to studies with chemoprophylaxis for DVT; and C, forest plots for the sensitivity analysis limited to studies with multivariate analyses;

and increased risk of DVT after TKA, even in patients who received chemoprophylaxis. Also, sensitivity analysis limited to studies with multivariate analysis suggested

a similar association, which indicates that the association between diabetes and increased risk of DVT after TKA was independent of the potential confounding factors,

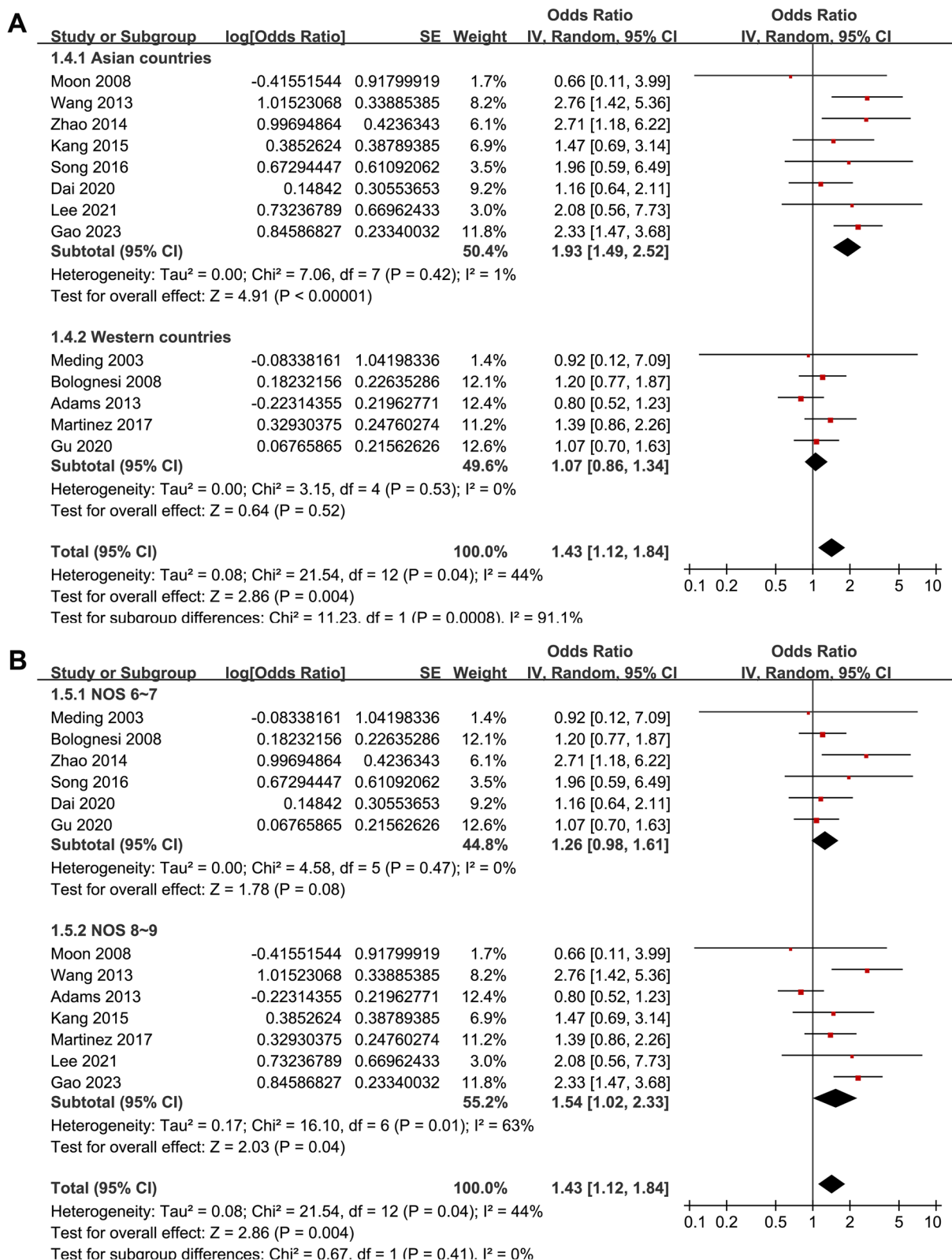


Fig. 3 Forest plots for the subgroup analyses regarding the association between diabetes and DVT after TKA; A, forest plots for the subgroup analyses according to the study country; and B, forest plots for the subgroup analyses according to the study quality score;

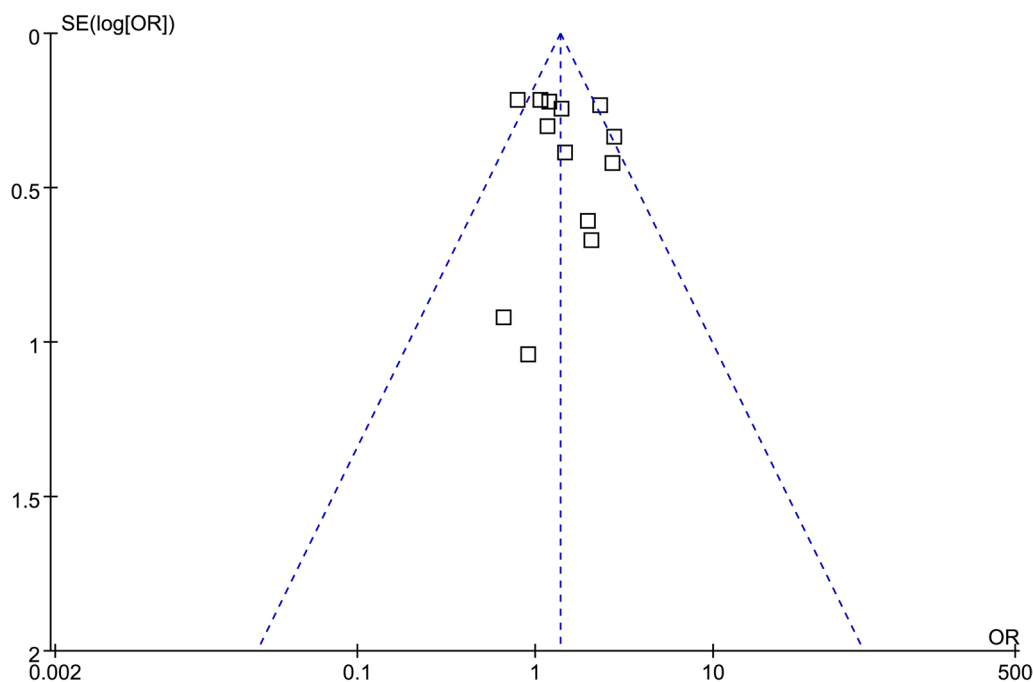


Fig. 4 Funnel plots for the publication biases underlying the meta-analyses of the association between diabetes and DVT after TKA

such as age. This is important because aging has been related to both diabetes [36] and postoperative DVT [37]. Finally, subgroup analysis according to study country showed that diabetes was associated with higher risk of postoperative DVT in studies from Asian countries, but not in Western countries. These findings suggest that ethnicity may affect the association between diabetes and risk of DVT after TKA, which may fully explain the source of heterogeneity. Taken together, these findings support that the preexisting diabetes may be a risk factor for postoperative DVT of patients after TKA.

The mechanisms underlying the association between diabetes and DVT after TKA remain unknown. Pathophysiologically, diabetes is related to chronic low-degree inflammation [38], oxidative stress response [39], endothelial dysfunction [40], and activated coagulative system [41], which are all likely to be involved in the pathogenesis of postoperative DVT. In addition, although we found that ethnicity of the patients may affect the association between diabetes and DVT after TKA, the reasons for the finding are also unknown. Previous studies have showed that the incidence of DVT of Asian patients after TKA is lower than patients other ethnicities [42]. The mechanisms underlying the influence of ethnicity on the association between preexisting diabetes and postoperative DVT should be determined in the future.

This meta-analysis has limitations. First, all of the included studies were of retrospective design, which

may expose the studies to the influences of selection and recall biases. Second, we were unable to determine if T1D and T2D have similar influence on the risk of DVT after TKA. Moreover, for sensitivity analysis limited to studies with chemoprophylaxis, none of the included studies used new oral anticoagulants (NOAC). It is important to determine if the association between diabetes and postoperative DVT remains in patients received NOAC for DVT prophylaxis. In addition, although sensitivity analysis limited to studies with multivariate analysis showed consistent results, we could not exclude the possibility of other residual factors which may confound the association between diabetes and postoperative DVT, such as the differences of antidiabetic treatments. Finally, this meta-analysis was based on observational studies, which could not determine a causative relationship between preexisting diabetes and the risk of DVT after TKA. It has to be mentioned that the above limitations were inherited to the design of meta-analysis of observational studies and meta-analysis based on study-level data rather than individual patient data, and accordingly, it is unable to further address the above limitations at current stage. Future prospective and clinical trials are warranted to address the above potential limitations.

Conclusions

In conclusion, results of the meta-analysis indicate that compared to patients with normoglycemia, patients with diabetes before the surgery had a higher incidence of

DVT after TKA, even in patients with the chemoprophylaxis of anticoagulants. The association between diabetes and DVT after TKA may be more remarkable in patients from Asian countries. Although these findings should be validated in large-scale prospective studies, results of the meta-analysis support that diabetes may be a risk factor for DVT in patients receiving TKA.

Acknowledgements

Not applicable.

Author contributions

JA and CZ designed the study. JA and LH performed database search, literature review, study identification, and data collection. JA, XM, YC, and CZ performed statistical analyses and interpreted the results. JA drafted the manuscript. CZ revised the manuscript. All the authors approved the submission of the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are included in this article.

Declarations

Ethics approval and consent to participate

Ethics approval was not required for this meta-analysis.

Informed consent

As this was a meta-analysis, data from individual participants were not obtained and will not be published.

Competing interests

The author declares that they have no potential competing interests.

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References

- Classification and Diagnosis of Diabetes. Standards of Medical Care in Diabetes-2022. *Diabetes Care*. 2022;45(Suppl 1):S17–38. <https://doi.org/10.2337/dc22-S002>.
- Liang D, Cai X, Guan Q, Ou Y, Zheng X, Lin X. Burden of type 1 and type 2 diabetes and high fasting plasma glucose in Europe, 1990–2019: a comprehensive analysis with the global burden of disease study 2019. *Front Endocrinol*. 2023;14:1307432. <https://doi.org/10.3389/fendo.2023.1307432>.
- Lovic D, Piperidou A, Zografou I, Grassos H, Pittaras A, Manolis A. The growing epidemic of diabetes mellitus. *Curr Vasc Pharmacol*. 2020;18(2):104–9. <https://doi.org/10.2174/1570161117666190405165911>.
- Strain WD, Paldanius PM. Diabetes, cardiovascular disease and the microcirculation. *Cardiovasc Diabetol*. 2018;17(1):57. <https://doi.org/10.1186/s12933-018-0703-2>.
- Grant B, Chowdhury TA. New guidance on the perioperative management of diabetes. *Clin Med*. 2022;22(1):41–4. <https://doi.org/10.7861/clinmed.2021-0355>.
- Karampelias V, Spanidis Y, Kehagias I, Chrysikos D. The postoperative redox status of patients with diabetes mellitus: a mini review. *Folia Med*. 2021;63(2):171–6. <https://doi.org/10.3897/fofmed.63.e54651>.
- Katz JN, Arant KR, Loeser RF. Diagnosis and treatment of hip and knee osteoarthritis: a review. *JAMA*. 2021;325(6):568–78. <https://doi.org/10.1001/jama.2020.22171>.
- Riviere C, Iranpour F, Auvinet E, Howell S, Vendittoli PA, Cobb J, et al. Alignment options for total knee arthroplasty: a systematic review. *Orthop Traumatol Surg Res*. 2017;103(7):1047–56. <https://doi.org/10.1016/j.otsr.2017.07.010>.
- Sloan M, Premkumar A, Sheth NP. Projected volume of primary total joint arthroplasty in the US, 2014 to 2030. *J Bone Joint Surg Am*. 2018;100(17):1455–60. <https://doi.org/10.2106/JBJS.17.01617>.
- Januel JM, Chen G, Ruffieux C, Quan H, Douketis JD, Crowther MA, et al. Symptomatic in-hospital deep vein thrombosis and pulmonary embolism following hip and knee arthroplasty among patients receiving recommended prophylaxis: a systematic review. *JAMA*. 2012;307(3):294–303. <https://doi.org/10.1001/jama.2011.2029>.
- Bosque J Jr, Coleman SI, Di Cesare P. Relationship between deep vein thrombosis and pulmonary embolism following THA and TKA. *Orthopedics*. 2012;35(3):228–33. <https://doi.org/10.3928/01477447-20120222-12>.
- Sun Y, Chen D, Xu Z, Shi D, Dai J, Qin J, et al. Deep venous thrombosis after knee arthroscopy: a systematic review and meta-analysis. *Arthroscopy*. 2014;30(3):406–12. <https://doi.org/10.1016/j.arthro.2013.12.021>.
- Qin W, Huang X, Yang H, Shen M. The influence of diabetes mellitus on patients undergoing primary total lower extremity arthroplasty: a systematic review and meta-analysis. *Biomed Res Int*. 2020;2020:6661691. <https://doi.org/10.1155/2020/6661691>.
- Wang S, Zhao Y. Diabetes mellitus and the incidence of deep vein thrombosis after total knee arthroplasty: a retrospective study. *J Arthroplasty*. 2013;28(4):595–7. <https://doi.org/10.1016/j.arth.2012.07.023>.
- Zhao Z, Wang S, Ma W, Kong G, Zhang S, Tang Y, et al. Diabetes mellitus increases the incidence of deep vein thrombosis after total knee arthroplasty. *Arch Orthop Trauma Surg*. 2014;134(1):79–83. <https://doi.org/10.1007/s00402-013-1894-3>.
- Gao J, Xue Z, Huang J, Chen L, Yuan J, Li J. Risk of deep vein thrombosis (DVT) in lower extremity after total knee arthroplasty (TKA) in patients over 60 years old. *J Orthop Surg Res*. 2023;18(1):865. <https://doi.org/10.1186/s13018-023-04339-7>.
- Meding JB, Reddeman K, Keating ME, Klay A, Ritter MA, Faris PM, et al. Total knee replacement in patients with diabetes mellitus. *Clin Orthop Relat Res*. 2003;416:208–16. <https://doi.org/10.1097/01.blo.0000093002.90435.56>.
- Moon HK, Han CD, Yang IH, Cha BS. Factors affecting outcome after total knee arthroplasty in patients with diabetes mellitus. *Yonsei Med J*. 2008;49(1):129–37. <https://doi.org/10.3349/ymj.2008.49.1.129>.
- Adams AL, Paxton EW, Wang JQ, Johnson ES, Bayliss EA, Ferrara A, et al. Surgical outcomes of total knee replacement according to diabetes status and glycemic control, 2001 to 2009. *J Bone Joint Surg Am*. 2013;95(6):481–7. <https://doi.org/10.2106/JBJS.L.00109>.
- Dai X, Ding W, Li H, Xu P, Huang Z, Zhu W, et al. Associations of serum lipids and deep venous thrombosis risk after total knee arthroplasty in patients with primary knee osteoarthritis. *Int J Low Extrem Wounds*. 2020;19(1):51–6. <https://doi.org/10.1177/1534734619868123>.
- Gu A, Wei C, Robinson HN, Sobrio SA, Liu J, Sculco TP, et al. Postoperative complications and impact of diabetes mellitus severity on revision total knee arthroplasty. *J Knee Surg*. 2020;33(3):228–34. <https://doi.org/10.1055/s-0038-1677542>.
- Lieberman JR, Bell JA. Venous thromboembolic prophylaxis after total hip and knee arthroplasty. *J Bone Joint Surg Am*. 2021;103(16):1556–64. <https://doi.org/10.2106/JBJS.20.02250>.
- Karasavvidis T, Bouris V, Xiang W, Tzavellas G, Charisis N, Palaodimos L, et al. Prophylaxis for venous thromboembolic events in elective total hip and total knee arthroplasty. *Curr Pharm Des*. 2022;28(10):771–7. <https://doi.org/10.2174/1381612828666220418090928>.
- Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA*. 2000;283(15):2008–12. <https://doi.org/10.1001/jama.283.15.2008>.
- Higgins J, Thomas J, Chandler J, Cumpston M, Li T, Page M, et al. *Cochrane Handbook for Systematic Reviews of Interventions* version 6.2. The Cochrane Collaboration. 2021; www.training.cochrane.org/handbook.
- Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2010; http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.

27. Higgins J, Green S. *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0. The Cochrane Collaboration. 2011; www.cochranehandbook.org.
28. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002;21(11):1539–58. <https://doi.org/10.1002/sim.1186>.
29. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ*. 1997;315(7109):629–34. <https://doi.org/10.1136/bmj.315.7109.629>.
30. Bolognesi MP, Marchant MH Jr, Viens NA, Cook C, Pietrobon R, Vail TP. The impact of diabetes on perioperative patient outcomes after total hip and total knee arthroplasty in the United States. *J Arthroplasty*. 2008;23(6 Suppl 1):92–8. <https://doi.org/10.1016/j.arth.2008.05.012>.
31. Kang J, Jiang X, Wu B. Analysis of risk factors for lower-limb deep venous thrombosis in old patients after knee arthroplasty. *Chin Med J*. 2015;128(10):1358–62. <https://doi.org/10.4103/0366-6999.156782>.
32. Song K, Xu Z, Rong Z, Yang X, Yao Y, Shen Y, et al. The incidence of venous thromboembolism following total knee arthroplasty: a prospective study by using computed tomographic pulmonary angiography in combination with bilateral lower limb venography. *Blood Coagul Fibrinolysis*. 2016;27(3):266–9. <https://doi.org/10.1097/MBC.0000000000000408>.
33. Martinez-Huedo MA, Jimenez-Garcia R, Jimenez-Trujillo I, Hernandez-Barraera V, Del Rio Lopez B, Lopez-de-Andres A. Effect of type 2 diabetes on in-hospital postoperative complications and mortality after primary total hip and knee arthroplasty. *J Arthroplasty*. 2017;32(12):3729–34. <https://doi.org/10.1016/j.arth.2017.06.038>.
34. Lee JK, Lee KB, Kim JI, Park GT, Cho YC. Risk factors for deep vein thrombosis even using low-molecular-weight heparin after total knee arthroplasty. *Knee Surg Relat Res*. 2021;33(1):29. <https://doi.org/10.1186/s43019-021-00109-z>.
35. Zhang S, Htet KS, Tan XY, Wang X, Wang W, Chua W. Short-duration chemoprophylaxis might reduce incidence of deep vein thrombosis in Asian patients undergoing total knee arthroplasty. *Knee Surg Relat Res*. 2020;32(1):58. <https://doi.org/10.1186/s43019-020-00077-w>.
36. Moen J. Diabetes, aging, and insulin's reponic features: review. *Curr Diabetes Rev*. 2023;19(7):e311022210506. <https://doi.org/10.2174/1573399819666221031140713>.
37. Kuperman EF, Schweizer M, Joy P, Gu X, Fang MM. The effects of advanced age on primary total knee arthroplasty: a meta-analysis and systematic review. *BMC Geriatr*. 2016;16:41. <https://doi.org/10.1186/s12877-016-0215-4>.
38. Hess K, Grant PJ. Inflammation and thrombosis in diabetes. *Thromb Haemost*. 2011;105(Suppl 1):S43–54. <https://doi.org/10.1160/THS10-11-0739>.
39. Vaidya AR, Wolska N, Vara D, Mailer RK, Schroder K, Pula G. Diabetes and thrombosis: a central role for vascular oxidative stress. *Antioxidants*. 2021. <https://doi.org/10.3390/antiox10050706>.
40. Dhananjayan R, Koundinya KS, Malati T, Kutala VK. Endothelial dysfunction in type 2 diabetes mellitus. *Indian J Clin Biochem*. 2016;31(4):372–9. <https://doi.org/10.1007/s12291-015-0516-y>.
41. Alzahrani SH, Ajjan RA. Coagulation and fibrinolysis in diabetes. *Diab Vasc Dis Res*. 2010;7(4):260–73. <https://doi.org/10.1177/1479164110383723>.
42. Lee WS, Kim KI, Lee HJ, Kyung HS, Seo SS. The incidence of pulmonary embolism and deep vein thrombosis after knee arthroplasty in Asians remains low: a meta-analysis. *Clin Orthop Relat Res*. 2013;471(5):1523–32. <https://doi.org/10.1007/s11999-012-2758-9>.

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