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Review

Risk factors for falls in patients with total hip arthroplasty and total knee arthroplasty: a systematic review and meta-analysis

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SUMMARY

Objective: Falls are common after total hip arthroplasty (THA) and total knee arthroplasty (TKA). While previous studies have investigated various risk factors for falls in patients following THA and TKA, no systematic reviews have summarized these risk factors. Therefore, the current systematic review aimed to summarize evidence regarding risk factors for falls in patients after THA and/or TKA.

Methods: MEDLINE, EMBASE, CINAHL, SPORTDiscus, and Physiotherapy Evidence Database (from inception to June 30, 2018) were searched. The methodological quality and quality of evidence of the included studies were assessed by two independent reviewers. Relevant data regarding participants' characteristics, study design, follow-up time points, and identified risk factors were extracted. Meta-analyses and narrative syntheses were performed.

Results: Twelve studies with a total of 1,292,689 participants were included. Twenty-nine identified risk factors for post-THA/TKA falls were classified into either inpatient or post-discharge risk factors. Key risk factors for both post-THA and/or post-TKA inpatient falls that showed moderate level of evidence included: postoperative complications or comorbidities and revision THA/TKA. Likewise, risk factors for post-discharge falls after THA and/or TKA that demonstrated moderate level of evidence included: medications, psychiatric diseases, living alone, prior history of TKA, falls history and female gender. The quality of the included studies varied and sample sizes were not justified.

Conclusions: This review summarized both non-modifiable and modifiable risk factors for post-THA/TKA falls. Our findings highlight the importance of developing strategies to lower the falls risk among patients following THA/TKA.

Introduction

Osteoarthritis (OA) is the third most debilitating musculoskeletal disorder worldwide, causing 17.1 million years lived with disability in 2010[1]. Knee joints are the most commonly affected[2], followed by hand and hip joints[3]. Hip and knee OA not only are painful progressive degenerative joint diseases, but also are the most pervasive cause of ambulatory dysfunction[4], and are independent risk factors for falls[5,6]. People with hip/knee OA are more likely to fall than the general population[7]. The annual fall rate for patients with hip OA was approximately 50%, and the fall rates for patients with knee OA and severe knee OA were up to 50% and 63%, respectively[5,6,8]. However, the 1-year incidence of falls in community-dwelling older people ranges from 10% to 33%[9,10] depending on age and ethnicity. The heightened fall rate and fall-related disability in patients with hip/knee OA may be attributed to the combined effects of pain, muscle weakness, impaired joint proprioception and poor balance[11,12].

Total hip or knee arthroplasty (THA/TKA) is a common surgical intervention for treating advanced hip/knee OA. These surgeries

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often alleviate pain, correct joint deformity and improve patients' quality of life[6,13,14], although some residual functional impacts can persist 12 months or more post-operatively. Despite the frequent post-operative symptomatic relief and functional improvements, 1% of post-THA patients and approximately 3% of post-TKA patients experience inpatient falls[15,16]. In fact, the prevalence rates of falls among patients with total hip arthroplasty (THA)/TKA after discharge are comparable to those among patients with severe hip/knee OA[17]. Importantly, approximately 40% of THA patients, and approximately 50% of pre-TKA fallers and 20% of pre-TKA non-fallers report falls in the first postoperative year[18,19].

While multiple studies have investigated risk factors for post-THA/TKA falls, no related systematic reviews have been identified in our systematic search. Since the number of THA and total knee arthroplasty (TKA) procedures are projected to increase by 24–673% in coming decades[20,21], it is paramount to summarize important risk factors for post-THA/TKA falls. Accordingly, this systematic review aimed to synthesize the evidence on risk factors for falls among patients after THA/TKA. These findings may help develop appropriate screening to guide fall prevention strategies after THA/TKA.

Methods

This review protocol was registered with PROSPERO (CRD42016043262). The current review followed the recommendation and guidelines of the Preferred Reporting Items of Systematic Reviews and Meta-analyses (PRISMA)[22].

Search strategy

Five electronic databases (MEDLINE, EMBASE, CINAHL, SPORTDiscus, and Physiotherapy Evidence Database) were searched from inception to June 30, 2018. The search keywords and Medical Subject Headings included [THA OR total hip replace* OR THA OR THR OR TKA OR total knee replace* OR TKR OR TKA] AND [fall* OR trip* OR balance] AND [risk factor* OR predict* OR prognosis*] (Appendix 1). A fall was defined as an individual unintentionally coming to rest on the floor or some lower level, not as a result of a major intrinsic event such as fainting, stroke[10,23]. The search terms were slightly modified to optimize the search in each database. The reference lists of all included studies were screened to identify relevant studies that might have been missed from the database search. Forward citation tracking of the included studies was conducted using Scopus. The corresponding authors of the included studies were contacted to obtain additional newly accepted articles.

Study selection

Primary studies of any study design that assessed risk factors for post-operative falls among patients undergoing THA and/or TKA were included. There were no limitations for language. Exclusion criteria were: articles that did not report statistics of risk factors (e.g., odds ratio, hazard ratio, relative risk, etc.), non-peer-reviewed articles, dissertations, conference proceedings, commentaries, or letters to the editor. Relevant systematic reviews were included to identify potential primary studies.

All identified titles and abstracts were independently screened by two reviewers (CL and RC) for eligibility. Any disagreements were discussed between the two reviewers. A third reviewer (AW) was consulted, if necessary. Full texts of potential articles were then retrieved and screened using the same procedure.

Data extraction

Two reviewers (CL and AW) independently extracted data from the included studies. Any disagreements between the reviewers were resolved by consensus. Data regarding participants' characteristics, study design, falls, risk factors and relevant statistics were extracted.

Risk of bias assessments

Two reviewers (CL and AW) independently evaluated the methodological quality of the included studies. All included cohort or case–control studies were evaluated by the Newcastle–Ottawa Scale (NOS)[24] for cohort studies and case–control studies, respectively. Cross-sectional studies were evaluated by the Appraisal tool for Cross-Sectional Studies (AXIS)[25]. The NOS for cohort or case–control studies comprises nine items. Each item was rated using a system of stars (*). A study could be awarded a maximum of one star for each item under the Selection and Exposure categories. A maximum of two stars could be given to the Comparability category. The AXIS tool comprises 20 items evaluating various aspects of methodological quality[25]. Each item has three rating options: 'Yes" (Y) - met the description of a particular evaluation criterion, 'no' (N) - did not meet a particular criterion or 'don't know' (?) - insufficient information to evaluate a particular criterion (Appendix 2).

The GRADE approach

Two authors (CL and AW) independently assessed the quality of evidence of each risk factor using the GRADEpro Guideline Development Tool Software program (Evidence Prime, Inc., 2015). The quality of evidence was rated at four levels: high, moderate, low, and very low[26].

Data synthesis

The risk factors for post-THA/TKA falls were categorized into inpatient falls and post-discharge falls. Meta-analyses were conducted on risk factors that were homogeneous across studies (e.g., patient types, study time points). Random effect models were used where heterogeneity (I^2) was larger than 0.3[27]. Narrative reviews were conducted for variables where meta-analyses were not feasible.

Results

Search results

Of 2,973 identified articles, 967 were duplicates; 2,006 underwent abstract screening and 215 full-text screening (Fig. 1). Twelve articles were included. They included 5 cross-sectional studies[16,18,28–30], six cohort studies[11,17,19,31–33], and 1 case–control study[10]. These studies involved 1,292,689 participants (42.17% men). One of these studies involved 1.1 million participants[29], and the median number of participants per study was 295 (interquartile range between 93 and 4,883). The mean age of the included participants ranged from 66.0 years to 75.9 years. Three studies reported risk factors for inpatient falls (Table I) and nine reported risk factors for post-discharge falls (Table II) following THA/TKA.

Study characteristics

All included studies involved patients undergoing unilateral and/or bilateral THA/TKA. Six studies included patients undergoing

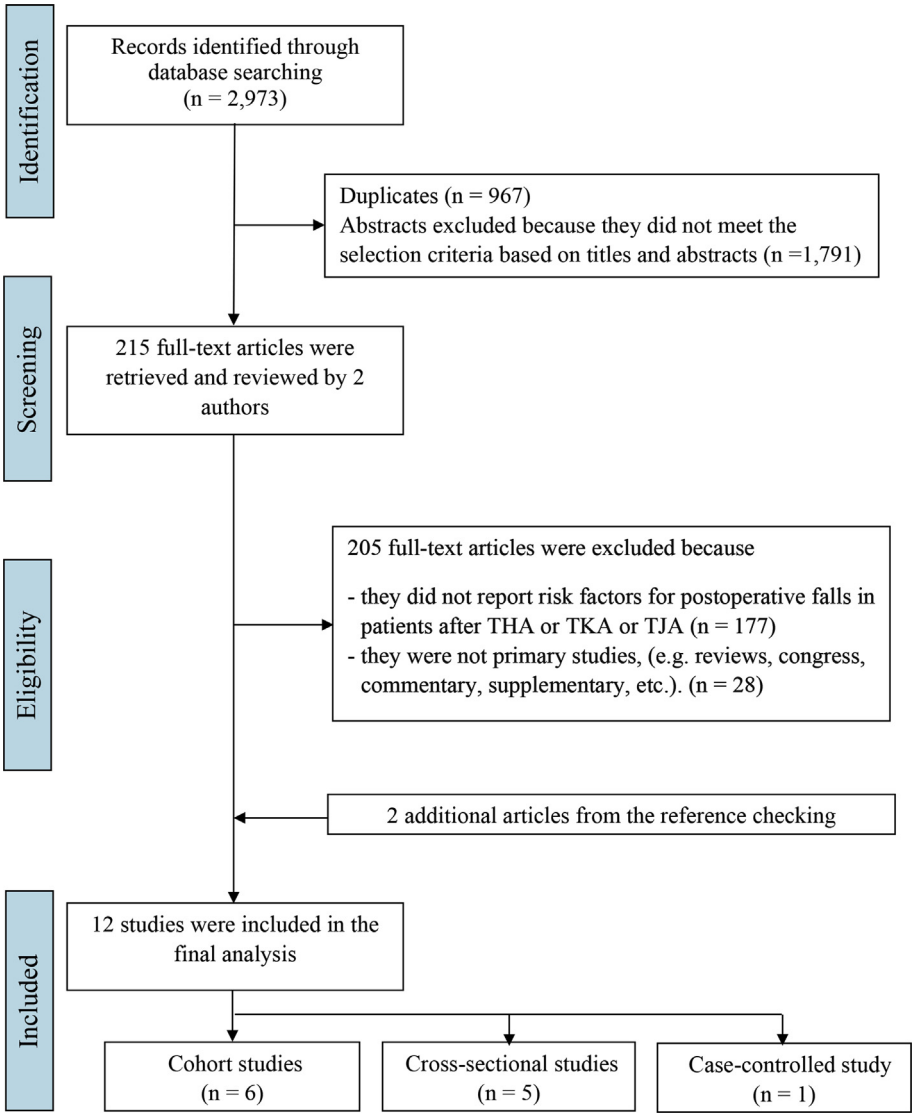

Fig. 1. Flow diagram of the searching and screening process.

primary THA and/or TKA only[16,18,19,30–32]. One study recruited both primary and revision THA/TKA patients[29]. Five studies did not provide details regarding primary or revision total joint replacements[10,11,17,28,33].

Fall incidence

Table III shows the reported post-operative fall incidence rates in the included studies. Two studies reported post-TKA inpatient fall rates to be 1.6%[28] and 2.7%[16]. A retrospective study found that 0.8% of post-THA/TKA patients fell in hospitals with an average of 2.1 falls per 1,000 inpatient days[29]. However, approximately 52% of post-THA/TKA patients fell within the first month after discharge[31]. The fall rates in the first 12 months after TKA ranged from 6.2% to 42.6%[10,17,19,30,32], while those following THA ranged from 25%[17] to 36 %[18]. The reported fall rate between 6 and 18 months post-TKA was 32.9%[11], and the fall rate between 12 and 24 months post-TKA was 3.14%, which might reflect longer term recovery and the effects of postoperative rehabilitation[32].

Risk factors for falls

Twenty-nine risk factors for post-THA/TKA falls were identified (Table IV). Risk factors were classified as moderate (n = 8), low (n = 19) and very low levels of evidence (n = 2) (Appendix 3). Since the included studies reported diverse risk factors and assessment methods, meta-analyses were only performed on six risk factors: advanced age (65–74 years & ≥75 years), male gender, electrolyte/fluid abnormalities, coagulopathy, history of falls, and reduced knee range of motion (ROM). A narrative synthesis was performed on the remaining risk factors.

A common risk factor for inpatient and post-discharge falls

Low level of evidence for inpatient falls

Advanced age. The meta-analysis from two studies (n = 1,279,505) revealed that compared to those aged below 55 years, patients aged 65–74 years and ≥75 years had 1.28 times and 1.60 times the risk of having inpatient falls, respectively (Fig. 2)[28,29]. Similarly, another inpatient study (n = 2,197) found that the risk of

Table I
The included studies that investigated risk factors for inpatient falls in patients after total hip/knee arthroplasty

Author/country	Study design	Populations and study design	Fall rate	Potential risk factors	Statistical analysis	Significant risk factors
Memtsoudis et al., 2014[27]; USA	Retrospective data extraction from database (2006–2010)	Patients after TKA; Sample size:,191,570 (71,246F); Age: 66.3 ± 10.4 yr	Incidence (1.6%)	Demographic variables; All hospital-related variable; All procedure-related variables (e.g., anesthesia technique, presence of peripheral nerve block); Comorbidity variables (e.g., dementia, sleep apnea, blood transfusion); Complication variables	Conventional logistic r egression; multilevel (random intercept) logistic regression	**Age (with reference to 45 −54 yr)** 55–64 yr: OR = 1.16, (95% CI: 1.00–1.34, $P < 0.01$) 65–74 yr: OR = 1.46, (95% CI: 1.26–1.68, $P < 0.001$) ≥75 yr: OR = 1.88, (95% CI: 1.63 −2.18, $P < 0.001$) **Males:** OR = 1.19, (95% CI: 1.10 −1.28, $P < 0.001$) **Anesthesia (with reference to general anesthesia)** Neuraxial anesthesia: OR = 0.70, (95% CI: 0.56–0.87, $P < 0.01$) **Complications/Comorbidities (with reference to the absence of complications/ comorbidities**) Electrolyte/fluid abnormalities: OR = 1.85, (95% CI: 1.68–2.04, $P < 0.001$) Psychosis: OR = 1.75, (95% CI: 1.45–2.11, $P < 0.001$) Sleep apnea: OR = 1.23, (95% CI: 1.08–1.39, $P < 0.01$) Obesity: OR = 1.16, (95% CI: 1.06–1.27, $P < 0.01$) Coagulopathy: OR = 1.36, (95% CI: 1.13–1.64, $P < 0.01$) Blood loss anemia: OR = 1.22, (95% CI: 1.00–1.49, $P < 0.01$) **With reference to patients with no anemia and no transfusion** Anemia, without transfusion: OR = 1.43, (95% CI: 1.28–1.59, $P < 0.001$) Anemia, with transfusion: OR = 1.70, (95% CI: 1.47–1.96, $P < 0.001$) No Anemia, with transfusion: OR = 1.98, (95% CI:1.77–2.21, $P < 0.001$)
Memtsoudis et al., 2012[28];USA	Cross-sectional from national inpatient database between 1998 and 2007	Patients after primary and revision unilateral THA or TKA; Sample size: 1,087,935 (668,334F); Age: 66.6 yr	0.8% (ranging from 0.4% to 1.3%) during the 10-year period; 2.1 falls per 1,000 inpatient days	Procedure type; Sex; Age group; Race; Hospital location; Hospital size; Alcoholism; Chronic pulmonary disease; Congestive heart failure; Diabetes, Liver disease; Coagulopathy; Neurologic disease; Peripheral vascular disease; Renal failure; Valvular disease; Electrolyte/ fluid disorder; Cancer; Pulmonary	Multivariate logistic regression; bootstrapping method	**Procedure type (reference to revision TKA)** Primary TKA: OR = 0.47, (95% CI: 0.43–0.52, $P < 0.0001$) Primary THA: OR = 0.52, (95% CI: 0.47–0.57; $P < 0.0001$) Males: OR = 1.07, (95% CI: 1.03 −1.11; $P = 0.03$) **Age (reference to 45–64 yr)** 65–74 yr: OR = 1.14, (95% CI: 1.08–1.20; $P < 0.0001$) ≥75 yr: OR = 1.38, (95% CI: 1.31 −1.45; $P < 0.0001$) **Race (reference to white)** Black: OR = 1.13, (95% CI: 1.02 −1.24; $P < 0.0144$), Hispanic: OR = 1.14, (95% CI: 1.00–1.30; $P < 0.0471$) **Hospital location (reference to urban area)** Rural area: OR = 1.16, (95% CI: 1.09–1.23; $P < 0.0001$) **Hospital size (reference to large size)** Smaller size (unclear definition): OR = 1.20, (95% CI: 1.14–1.27; $P < 0.0001$) **Comorbidity (reference to the**

Table I (*continued*)

Author/country	Study design	Populations and study design	Fall rate	Potential risk factors	Statistical analysis	Significant risk factors
				circulatory disease Hospital record periods		**absence of the disease)** Alcoholism: OR = 1.42, (95% CI: 1.17–1.74; $P < 0.0005$) Chronic lung disease: OR = 1.11, (95% CI: 1.05–1.18; $P < 0.0007$) Congestive heart failure: OR = 1.25, (95% CI: 1.13–1.38; $P < 0.0001$) Coagulopathy: OR = 1.68, (95% CI: 1.46–1.92; $P < 0.0001$), Neurologic disease: OR = 1.42, (95% CI: 1.27–1.59; $P < 0.0001$) Electrolyte/fluid abnormalities: OR = 1.81, (95% CI: 1.69–1.93; $P < 0.0001$) Pulmonary circulatory disease: OR = 3.17, (95% CI: 2.66–3.50; $P < 0.0001$)
Wasserstein et al., 2013[16]; Canada	Cross-sectional study of registry or databases	Patients underwent primary TKA; Sample size: 2,197 (1,449F); Age: 66.0 ± 11.0 yr;	2.7%	Age; Gender; Simultaneous bilateral TKA; BMI; Nerve block location; Type of block administration	Multivariate logistic regression model	**The type of block administration (reference to single bolus)** Continuous catheter femoral nerve block: OR = 4.4, (95% CI: 1.04–18.2; $P = 0.04$) Obesity: OR = 2.40, (95% CI: 1.30–4.50; $P = 0.005$) Age >66 yr (for each additional year): OR = 1.04, (95% CI: 1.00–1.07; $P = 0.008$)

F = Female; KL = Kellgren and Lawerence grade; NA = Not applicable; THA = Total hip arthroplasty; TKA = Total knee arthroplasty; yrs = Years, BMI = body mass index, OR = odd ratio; P = significant different; CI = confident interval.

inpatient falls increased by 4% for every additional year above 66 years[16].

Low level of evidence for post-discharge falls

Advanced age. Jorgensen and Kehlet[31] ($n = 5,145$) demonstrated that age was a risk factor for post-THA/TKA falls after 90-day discharge (OR:1.05, for every additional year at ages between 39 and 96 years). Another study ($n = 376$) found that individuals aged ≥70 years were 21.5 times more likely to fall than younger adults at 1-year post-TKA[32].

Risk factors for inpatient fall (for THA/TKA patients)

Moderate level of evidence

Revision THA/TKA. Patients with revision THA/TKA (ORs:1.92–2.13) were more likely to report inpatient falls than white and those with primary THA/TKA[29].

Comorbidities and complications. Three studies ($n = 1,287,223$) found that inpatient post-THA/TKA falls increased in the presence of surgery-related complications or comorbidities (ORs: 1.11–3.17)[16,28,29]. Specifically, electrolyte/fluid abnormalities (pooled ORs:1.82; 95%CI: 1.73–1.93)[28,29], and coagulopathy (pooled ORs:1.53; 95%CI: 1.24–1.87)[28,29] were associated with a higher risk of inpatient falls (Fig. 3).

Low level of evidence

Male gender. The meta-analysis from two studies ($n = 1,285,026$)[28,29] found that male had significantly higher risk of inpatient falls than female after THA/TKA (pooled ORs:1.12, 95%CI: 1.01–1.25) (Fig. 3).

Three risk factors were identified in the same study ($n = 1,087,935$)[29]. Specifically, staying in rural and small hospitals significantly increased the risk of inpatient falls by 16–20%[29], while black/Hispanic races (ORs:1.13–1.14) were more likely to report inpatient falls than white[29].

Risk factors for inpatient fall (for TKA patients only)

Low level of evidence

Anemia. One study ($n = 191,570$) showed that anemia was a significant risk factor for post-TKA inpatient falls regardless of blood transfusion (ORs:1.43–1.98). Compared to non-anemic patients without blood transfusion, non-anemic patients receiving blood transfusion during surgery doubled the risk of post-TKA falls[28]. However, this study did not clarify whether these patients had postoperative anemia.

Anesthesia techniques. Compared to general anesthesia, a study ($n = 191,570$) reported that the use of neuraxial anesthesia reduced inpatient post-TKA fall risk (OR:0.70)[28].

Wasserstein *et al.* ($n = 2,197$) found that the perioperative continuous catheter femoral nerve block (FNB) administered to TKA patients elevated fall risk >4-fold when compared to a single shot FNB[16].

Risk factors for post-discharge falls (for THA/TKA patients)

Moderate level of evidence

Medications. Two studies reported medications as risk factors for post-discharge falls. Ikutomo *et al.* ($n = 214$) found that THA patients taking medications administrated after surgery were 4 times more likely to fall after hospital discharge compared with those not taking medications. However, the types, doses, and number of medications were not reported[18]. Another study ($n = 5,145$) found that THA and/or TKA patients with pharmacologically treated

Table II
The included studies investigating risk factors for falls in patients with total hip/knee arthroplasty after discharge

Author/country	Study design	Populations and study design	Follow-up-period	Incidence/fall rate	Potential risk factors investigated	The time point at which the ORs were calculated	Significant risk factors
Jorgensen and Kehlet, 2013[30]; Denmark	Prospective, multicenter study	Patients receiving fast-track primary unilateral THA or TKA; Sample size: 5,145 (2,932F); 2,696 THA, 2,449 TKA Age: 67.4 ± 10.8 yr	A 90-day postoperative period	Fall-related hospital admission: 1.6%; 51.8% fell within the 1st month after discharge	Age; Gender; Smoking; Walking aids; Types of arthroplasty BMI; Use of walking aid; Social situation; Diabetes; Pharmacologically treated psychiatric disease; Length of hospital stay ≤4 days	After 90-day follow up period	Age 39–96 yrs: OR = 1.05, (95% CI: 1.02–1.08; $P = 0.001$) Living alone: OR = 2.09, (95% CI: 1.20–3.62; $P = 0.009$) Pharmacologically treated psychiatric disease: OR = 2.80, (95% CI: 1.42–5.50; $P = 0.001$)
Ikutomo et al., 2015[18]; Japan	Cross-sectional	Patients after primary THA ≥ 1 yr (2–8 years after THA); Sample size: 214 (203F); Age: 66.0 ± 8.7 yr	NA	Fall in the last year: 36%	Age; Sex; BMI; Medications; Comorbidities; Bilateral THA; Postoperative duration; Total Oxford Hip Scores; Use of a walking aid; Walking Capacity	Risk for falling in the last 12 months	Medications administered after surgery (%): OR = 4.09, (95% CI: 1.90–8.80; $P < 0.001$) Shorter Postoperative duration (yr): OR = 1.12, (95% CI: 1.02–1.23; $P = 0.014$)
Matsumoto et al., 2012[11]; Japan	Prospective cohort	Patients with bilateral or unilateral TKA; Sample size: 74 (66F); standard medial parapatellar approach + 4 months rehabilitation; Age: 75.7 ± 5.8 yr	Baseline: Post-TKA between six6 and 12 months; reassessed after 6 months; monthly pre-stamped postcards	32.9% during 6-month monthly follow-ups	JKOM; GDS; MFES; Preoperative knee flexion, extension, ROM of flexion and extension; Preoperative (6–12 months) knee flexion, extension, range of flexion and extension; Ankle dorsiflexion and plantarflexion ROM; Knee instability; Quadriceps strength; Hallus valgus; Limitation of ankle mobility; Kyphosis; One-leg stand; 10-m walk test	6 months after baseline assessment	Every 10° decrease in postop ROM of knee flexion (between 80° and 140°): OR = 3.61, (95% CI: 1.15–11.36, $P = 0.028$) Every 5° decrease in postop ROM of ankle plantarflexion between 40° and 70°: OR = 1.68, (95% CI: 1.06–2.67, $P = 0.028$)
Matsumoto et al., 2014[10]; Japan	Retrospective case–control study	Patient Gp: Post-TKA patients with bilateral or unilateral; Sample size: 81 (74F); Age: 75.9 ± 2.3 yr; Ctl Gp: Healthy participants; Sample size: 80 (68F); Age: 75.7 ± 3.0 yr	Post TKA from 1 to 7 years	Incidence of falls in the last 12 months Patient Gp: 38.2% Ctl Gp: 23.8% ($p = 0.041$)	Surgery information (e.g., year after operation); Physical problems (e.g., kyphosis, hallux valgus); Medical comorbidities; Ambulatory ability (e.g., walking aids);	2–6.5 years after TKA	Patient Gp: The presence of kyphosis: OR = 3.91, (95% CI: 1.11–13.73; $P = 0.03$)

					Categorized walking distance; Functional status (exercise habits, fear of falls, stairs negotiation etc) Knee pain; knee flexion range of motion; other joint problems		
Smith et al., 2016[17]; Britain	Prospective cohort from Osteoarthritis Initiative database	Patient Gp: Post THA or TKA patients within the first 12 months; Sample size: THA: 104 (61F), TKA: 165 (96F); Age: 69.0 ± 9.1 yr; Ctl Gp: Non-THA: 4,692 (2,743F), Non-TKA: 4,631 (2708F); Age: 66.8 ± 9.0 yr;	Post- THA/TKA 12 months	Fall rate of post-THA patients in the last 12 months: 25% Fall rate of post-TKA patients in the last 12 months: 26.1% Fall rate of non-THA/TKA individuals in the last 12 months: 27.0−27.1%	Age; Gender; Ethnicity: marital status: previous THA or TKA; Diagnosis of hip OA or knee OA; Bisphosphonate usage; Underwent TKA Physician-diagnosis of hip OA or knee OA	At first 12-month after THA or TKA	People after THA: Having undergone a previous TKA: OR = 6.67 (95% CI: 1.89−25.00; $P < 0.05$) People after TKA: Bisphosphonate use: OR = 1.25, (95% CI: 1.00−1.56; $P < 0.05$)
Si et al., 2017[31]; China	Prospective cohort	Underwent primary and unilateral TKA; Sample size at baseline: 376 (259F), post-TKA 1st year: 321, post-TKA 2nd year: 350; Age: 68.9 ± 8.2 yr;	Pre-TKA, 1-year & 2-year post-TKA	The fall rate in 1st year post-TKA: 6.23% The fall rate in 2nd year post-TKA: 3.14%	Age; Sex; BMI; KL grade of contralateral knee; Incision length; Operative time; Prosthesis type	Pre-TKA, 1-year & 2-year after TKA	**1-year post-TKA** Age: ≥70 yrs: OR = 21.46, (95% CI: 2.75−167.75, $P < 0.05$) Female: OR = 5.54, (95% CI: 1.17−26.20, $P < 0.05$) Contralateral knee with KL grade ≥ 3: OR = 6.54, (95% CI: 2.34−18.28, $P < 0.05$) **2-year post-TKA** Contralateral knee with KL grade ≥ 3: OR = 16.97, (95% CI: 3.45−83.64, $P < 0.05$)

Soison et al., 2014[29];
Thailand
	Cross-sectional study	Post-TKA 38.9 ± 16.6 months;
		Sample size: TKA: 54 (46F);
		Age: 67.0 ± 8.1 years;
			NA	1-year prevalence rate of falls: 42.6%	Age; gender; vision problems; weight; height; BMI;
					VAS;
					WOMAC pain;
					WOMAC function;
					WOMAC stiffness; Total WOMAC;
					Limited knee joint ROM (>0° to < 120°);
					Heights
						7 months−73 months after TKA	#WOMAC pain
							OR = 1.06 (95% CI: 1.01−1.10, $P = 0.028$)
							(unclear dependent and independent variables)
							#WOMAC stiffness
							OR = 0.87, (95% CI: 0.79 to 0.96, $P = 0.007$)
							(unclear dependent and independent variables)
							#Limit knee ROM:
							OR = 1.80, (95% CI = 1.14−2.86, $P = 0.013$) (unclear dependent and independent variables)

Swinkels et al., 2009[19]; Britain	Prospective cohort	Patients with primary TKA; TKA: 99 (63F); Age: 73.4 ± 4.9 yr;	3-month pre-TKA 3-month post-TKA 6-month post-TKA 9-month post-TKA 12-month post-TKA	The fall rate in each of 3-month post-TKA: 11.7−11.8% The fall rate in 12-month post-TKA: 24.2%	Age; Gender; Number of comorbid condition; Number of baseline medications; Number of	12-month post-TKA	Preoperative fall history: OR = 7.75, (95% CI: 1.72−35.71; $P = 0.008$) Preoperative GDS score: OR = 1.27, (95%

(*continued on next page*)

Table II (*continued*)

Author/country	Study design	Populations and study design	Follow-up-period	Incidence/fall rate	Potential risk factors investigated	The time point at which the ORs were calculated	Significant risk factors
					cardiovascular medications; Uptake of anti-depressants; Self-reported eye problems; Self-reported hearing problems; Preoperative fall history; WOMAC; Balance confidence scores (ABC-UK); Preoperative GDS score		CI: 1.02−1.57; $P = 0.031$)
Tsonga et al., 2016[32]; Greece	Prospective cohort	Patients receiving TKA; TKA: 68 (57F); Age: 73.0 ± 5.3 yr;	2-week pre-TKA 12-month post-TKA	The fall rate in 12-month post-TKA: 22.1%	Age; Gender; BMI; History of fall; Fear of falling; Pain elsewhere in the body; Chronic disease; Complications; Social environment; Other arthroplasty; SF-36; WOMAC; PASE; TUG; ABC; BBS	12-month post-TKA	History of fall: OR = 7.23, (95% CI: 1.28−44.01; $P = 0.025$) Fear of falling after surgery: OR = 11.90, (95% CI: 2.20−64.20; $P = 0.004$)

Ctl Gp = Control group; Exp Gp = Experimental group; F = Female; GDS = Geriatric Depression Scale; JKOM = Japanese Knee Osteoarthritis Measure; KL = Kellgren and Lawerence grade; MFES = Modified Fall Efficacy Scale; NA = Not applicable; THA = Total hip arthroplasty; TKA = Total knee arthroplasty; yrs = Years, BMI = body mass index, OR = odd ratio; P = significant different; CI = confident interval: WOMAC = Western Ontario and McMasters Osteoarthritis Index; ABC = Activities-specific Balance Confidence; SF = short from, PASE = Physical Activity Scale for the Elderly; TUG = Timed Up and GO test; BBS = Berg Balance Scale.
#β was used in the original study. In order to present the risk factors across studies into the same unit, β was converted to OR.

Table III
Summary of fall rates following total hip arthroplasty (THA) or total knee arthroplasty (TKA)

Fall rate	THA patients	TKA patients
a. Within several days after surgery (Inpatient)	#2.1 falls per 1,000 inpatient days[28]	
	NA	1.6%[27]
		2.7%[16]
b. Within first month after discharge	#51.8%[30]	
c. 12 months after discharge	25.0%[17]	6.2%[31]
	36.0%[18]	22.1%[32]
		24.2%[19]
		26.1%[17]
		38.2%[10]
		42.6%[29]
d. 6–18 months after discharge	NA	32.9%[11]
e. 12–24 months after discharge	NA	3.1%[31]

Note: # data was collected from both THA and TKA patients; NA is no data available
The number in the parentheses is the reference of an included study.

psychiatric diseases were three times more likely to fall post-operatively[31] although the types and doses of psychiatric medications were not reported.

Living alone. One study ($n = 214$) found that THA and/or TKA patients living alone doubled the risk of postoperative falls as compared to those living with others[31].

Risk factors for post-discharge falls (for THA patients)

Moderate level of evidence

History of TKA. One study ($n = 4,796$) found that a history of TKA increased >6-fold risk of falls in post-THA patients within the first year post-surgery[17].

Low level of evidence

Surveillance period. Ikutomo *et al.* ($n = 214$) found that shorter the time between THA and falls surveillance period was associated with a higher risk of post-THA falls (OR:1.12)[18].

Risk factors for post-discharge falls (for TKA patients)

Moderate level of evidence

History of falls. The meta-analysis of data from two studies ($n = 167$) revealed that a history of falls increased the risk of post-TKA falls by 7.5 times[19,33] (Fig. 4).

Female gender. Unlike inpatient falls, one study ($n = 321$) revealed women were 4 times more likely to experience post-discharge falls than men within the first year after TKA[32].

Low level of evidence

Seven risk factors for post-discharge falls showed low level of evidence. The meta-analysis on two studies ($n = 128$) found that for

Table IV
Summary of risk factors for falls following total hip arthroplasty (THA) or total knee arthroplasty (TKA)

Risk factors for falls	Both THA and TKA patients	THA patients	TKA patients
a. Common factors for inpatient and post-discharge falls	Advanced age (inpatient falls) 65–74 yrs (pooled OR: 1.28)* (L) ≥75 yrs (pooled OR: 1.60)# (L) Advanced age (post-discharge falls) 39–96 yrs (for every additional year) (OR: 1.05–21.46)# (L)	NA	NA
b. Inpatient setting	Revision THA/TKA (OR: 1.92–2.13)# (M)	NA	Neuraxial anesthesia (reduced risk) (OR: 0.70)# (L)
	Other postoperative complications or comorbidities (OR: 1.11–3.17)# (M)		
	Electrolyte/fluid abnormalities (pooled OR: 1.82)# (L)		Anemia (OR: 1.43–1.98)# (L)
	Coagulopathy (pooled OR: 1.53)*(L)		Perioperative continuous catheter FNB (OR: 4.40)* (L)
	Rural hospitals (OR: 1.16)# (L)		
	Males gender (pooled OR: 1.12)* (L)		
	Small size hospitals (OR: 1.20)# (L)		
	Minority race (black and Hispanic) (OR: 1.13–1.14)* (L)		
c. Post-discharge setting	Medications (OR: 4.09)# (M)	Prior history of TKA(OR: 6.67)* (M)	History of falls (pooled OR: 7.53)* (M)
	Pharmacologically treated psychiatric diseases (OR: 2.80)# (M)	Shorter surveillance period(OR: 1.12)* (L)	Females gender (OR: 5.54)* (M)
	Living alone (OR: 2.09)# (M)		Contralateral knee KL grade ≥ 3 (OR: 6.54–16.97)* (L)
			Reduced ankle ROM (OR: 1.68)* (L)
			Preoperative GDS score (OR: 1.27)* (L)
			Reduced knee ROM (pooled OR: 2.0810)* (L)
			Bisphosphonate administration (OR: 1.25)* (L)
			Post-operative fear of falling (OR: 11.90)# (L)
			Hyper-kyphosis (OR: 3.91)* (L)
			Post-operative WOMAC pain (OR: 1.06)* (VL)
			Post-operative WOMAC stiffness (reduced risk) (OR: 0.87)# (VL)

Note: *$P < 0.05$; #$P < 0.01$, FNB = Femoral nerve block, GDS = Global depression scale; KL = Kellgren and Lawrence; ROM = range of motion; WOMAC = Western Ontario & McMaster University Osteoarthritis Index,: # information was collected from both THA and TKA patients, yrs = year, NA is no data available; The certainty of evidence by Cochrane GRADE approach (M) = moderate, (L) = low, (VL) = very low.

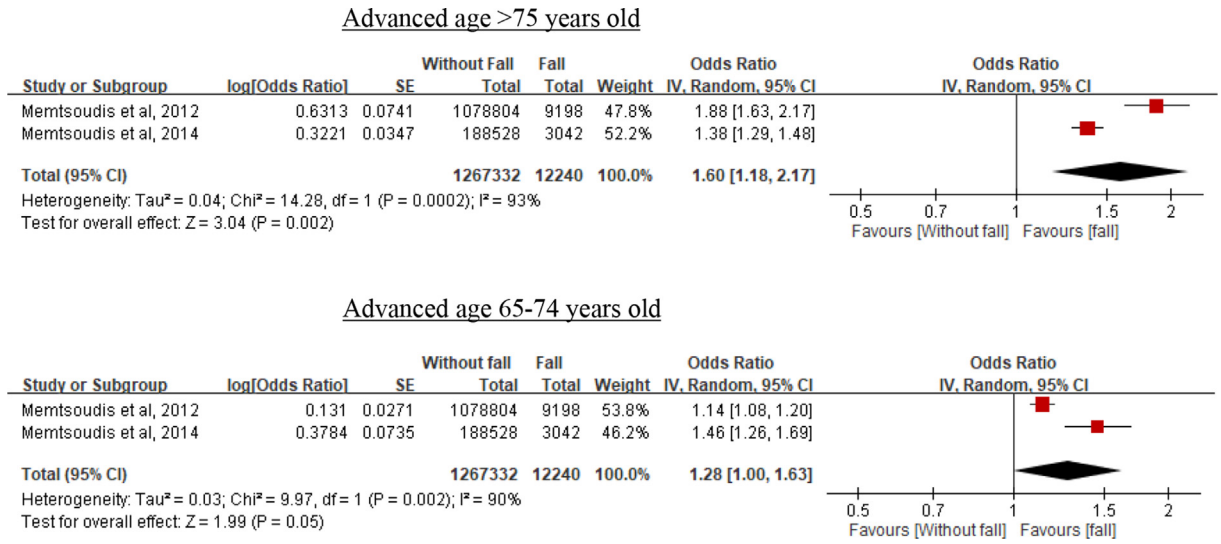

Fig. 2. Forest plots of common risk factor (advanced age) for inpatient falls after total hip arthroplasty (THA) or total knee arthroplasty (TKA).

every 10° decrease in postoperative knee flexion ROM (between 80° and 140° or less than 120°) doubled the risk of post-TKA falls (Fig. 4)[11,30]. Matsumoto and colleagues ($n = 74$) also found that with every 5° decrease in postoperative ankle plantarflexion ROM (between 40° and 70°) increased the risk of post-TKA falls by 68%[11]. An additional point increase in the preoperative Geriatric Depression Scale (GDS) score increased 1.3 times the risk of post-TKA falls ($n = 99$)[19]. Additionally, the bisphosphonate use ($n = 4{,}796$) increased the risk of falls by 25%, and doubled the risk of bone fracture in the first post-TKA year[17]. However, no information was provided regarding whether bisphosphonate was prescribed before or after a fall/fracture incident[17]. Tsonga *et al.* ($n = 68$) found that patients with fear of falling postoperatively had 12 times greater risk of post-TKA falls[33]. Si *et al.* ($n = 321$) reported that patients with a contralateral knee with Kellgren and Lawerence grade (KL) grade ≥ 3 out of 4 had 6-fold and 17-fold higher risk of falls in first

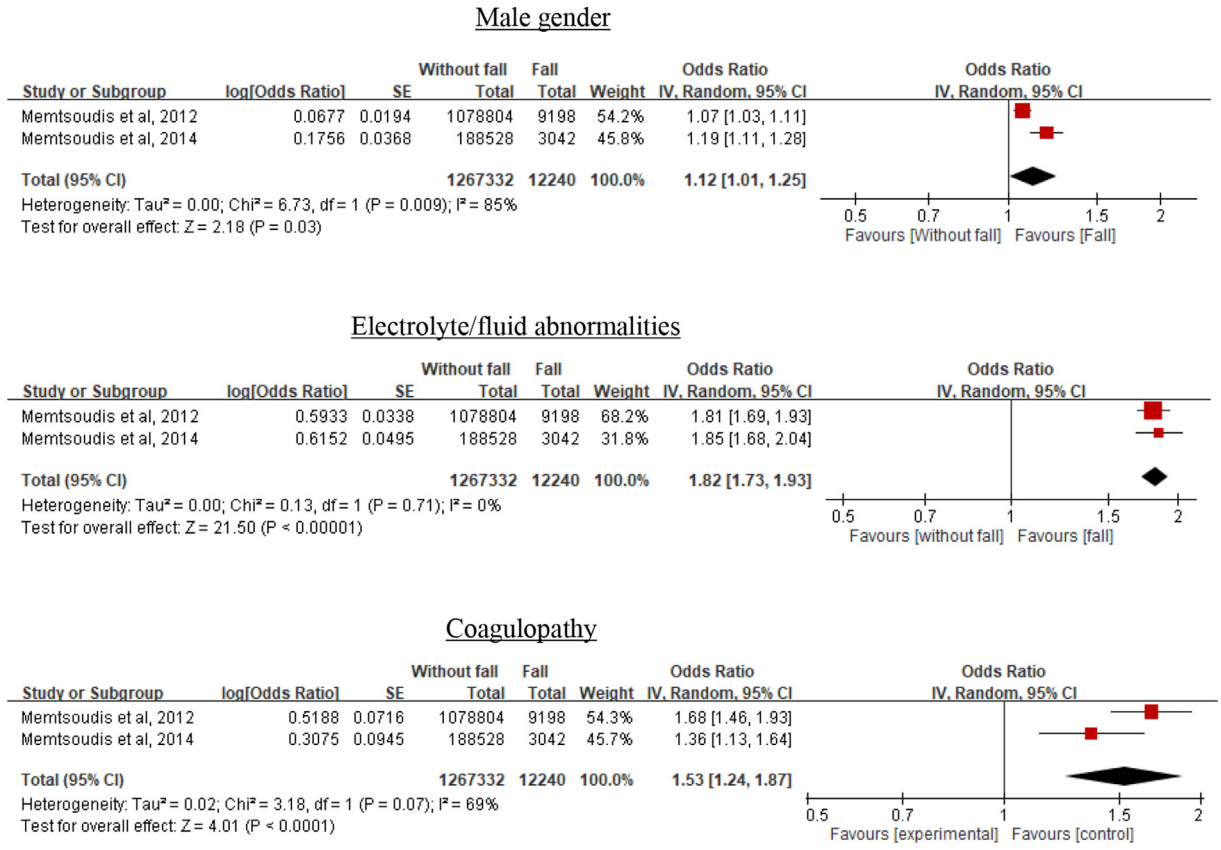

Fig. 3. Forest plots of risk factors for inpatient falls after total hip arthroplasty or total knee arthroplasty.

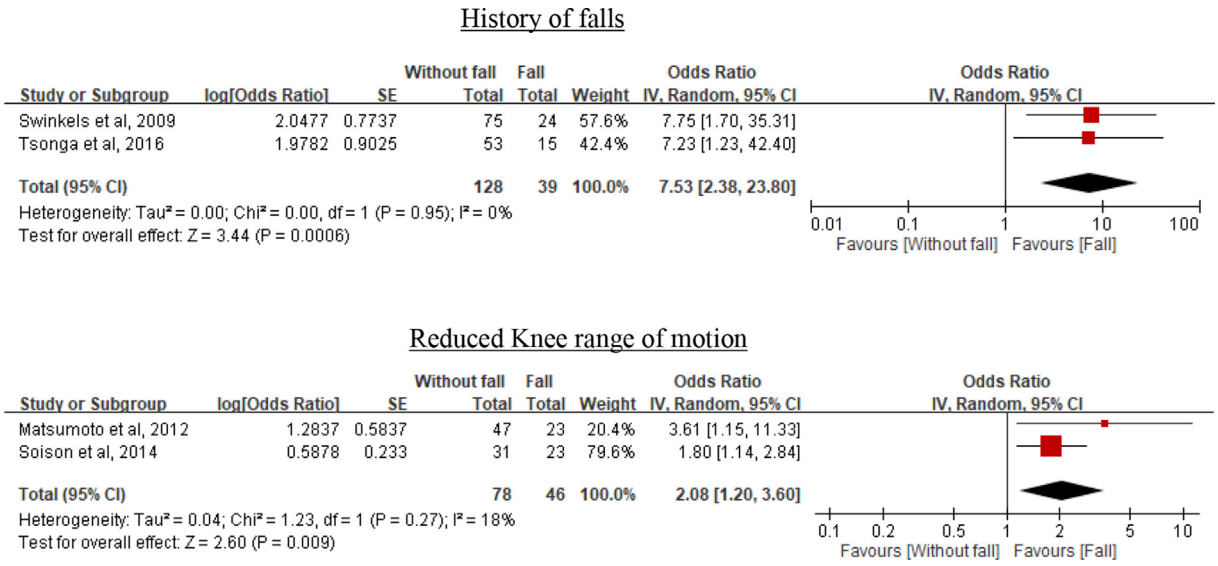

Fig. 4. Forest plots of risk factors for post-discharge falls after total knee arthroplasty.

and second post-TKA year, respectively[32]. Furthermore, post-TKA patients with hyperkyphosis ($n = 81$) were 4 times more likely to fall than those without kyphosis although the definition of hyperkyphosis was unclear[10].

Very low level of evidence

TKA patients ($n = 54$) with higher post-operative pain scores on the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (OR:1.06) and lower post-operative stiffness scores on WOMAC (OR:0.87) increased their risk of falls[30]. However, since the dependent and independent variables used in the multiple regression model of the study were unclear, the association between falls and post-operative pain or stiffness was unclear.

Risk of bias assessments

Of the 12 included studies, all six cohort studies[11,17,19,31–33] and the 1 case–control study[10] were rated as high quality. For the cross-sectional studies, one study met 17 out of 20 assessment criteria, 3 studies met 13 to 15 criteria[16,28,29], and one study met 10 criteria[30]. (Tables V and VI). None of the included studies justified their sample sizes or provided information about their non-response rates. One cross-sectional study did not provide detailed methodology or clear results[30].

Discussion

This systematic review summarizes various reported risk factors for falls in patients following THA and/or TKA. The reported inpatient and post-discharge fall rates after THA/TKA ranged from 0.8% to 2.7% (within the first few days after surgery) and from 3.14% to 51.8% (within 24 months after surgery), respectively. Although 29 risk factors for falls were identified, only revision THA/TKA, postoperative complications or comorbidities, medications, pharmacologically treated psychiatric diseases, living alone, prior history of TKA, history of falls and female gender demonstrated moderate level of evidence. While higher age is a common risk factor for both inpatient and post-discharge falls, other risk factors are specific to either inpatient or post-discharge falls among patients with THA/TKA.

Common risk factors for postoperative falls

Older ages are known to be a risk factor for falls in hospitals. Prior research evaluating an orthopedic ward records showed that the odds of falling increased by 7% per year above the age of 65 years among musculoskeletal patients (88% of this sample underwent THA/TKA)[15]. Since most patients with total joint arthroplasty are relatively old[18], age-related neuromuscular changes and degenerative joint deformity may compromise balance and functional ability[28,34], increasing the propensity to fall following THA/TKA.

Table V
Quality appraisal of studies – Newcastle–Ottawa Scale (NOS)

Items	1	2	3	4	5	6	7	8
Case-controlled study								
Matsumoto *et al.* 2014[10]	*	*	*	*	*	*	*	*
Cohort study								
Matsumoto *et al.* 2012[11]	*	*	*	*	*	*	*	*
Jorgensen and Kehlet 2013[29]	*	*	*	*	*	*	*	*
Smith *et al.* 2016[17]	*	*	*	*	*	*	*	*
Si *et al.* 2017[30]	*	*	*	*	*	*	*	*
Swinkels *et al.*, 2009[19]	*	*	*	*	*	*	*	*
Tsonga et al., 2016[31]	*	*	*	*	*	*	*	*

Note: * = An award for each numbered item. The details of each item can be found in the Appendix 2.
For Case-controlled study.
1) Is the case definition adequate?
2) Representativeness of the cases
3) Selection of Controls
4) Definition of Controls
5) Comparability of cases and controls on the basis of the design or analysis
6) Ascertainment of exposure
7) Same method of ascertainment for cases and controls
8) Non-Response rate
For Cohort study.
1) Representativeness of the exposed cohort
2) Selection of the non exposed cohort
3) Ascertainment of exposure
4) Demonstration that outcome of interest was not present at start of the study
5) Comparability of cohorts on the basis of the design or analysis
6) Assessment of outcome
7) Was follow-up long enough for outcomes to occur
8) Adequacy of follow up of cohorts

Table VI
Quality appraisal of studies – Appraisal tool for Cross-Sectional Studies (AXIS)

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ikutomo *et al.* 2015[18]	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N	Y
Memtsoudis *et al.* 2014[27]	Y	Y	N	?	Y	Y	?	Y	Y	Y	Y	Y	?	?	Y	N	Y	Y	N	N
Memtsoudis *et al.* 2012[28]	Y	Y	N	Y	Y	Y	?	Y	?	Y	?	Y	?	?	Y	Y	Y	Y	N	N
Wasserstein *et al.* 2013[16]	Y	Y	N	Y	Y	Y	?	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	N	Y
Soison *et al.* 2014[29]	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	N	N	N	N	N	N	N	N	Y

Note: Key to symbols: Y = Yes, N = No, ? = Don't know. The details of each item can be found in the Appendix 2.

1) Were the aims/objectives of the study clear?
2) Was the study design appropriate for the stated aim(s)?
3) Was the sample size justified?
4) Was the target/reference population clearly defined? (is it clear who the research was about?)
5) Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?
6) Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?
7) Were measure undertaken to address and categorise non-responders?
8) Were the risk factor and outcome variables measured appropriate to the aims of the study?
9) Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?
10) Is it clear what was used to determine statistical significance and/or precision estimates? (e.g., *p*-values, confidence intervals)
11) Were the methods (including statistical methods) sufficiently described to enable them to be rejected?
12) Were the basic data adequately described?
13) Does the response rate raise concerns about non-response bias?
14) If appropriate, was information about non-responders described?
15) Were the results internally consistent?
16) Were the results presented for all the analyses described in the methods?
17) Were the authors' discussions and conclusions justified by the results?
18) Were the limitations of the study discussed?
19) Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?
20) Was ethical approval or consent of participants attained?

Risk factors for inpatient falls

Male had more inpatient fall after THA/TKA than women[28,29], whereas women with TKA had more falls than men post-hospital discharge[32]. Male patients may have tended to overestimate their ability and be more eager to take risks[35], which may increase the risk of falls in hospital. Conversely, the higher post-discharge fall risk in women may be attributed to their greater tendency to report falls and seek assistance from caregivers[36]. Further, since women are less likely to regain their balance following a perturbation[37], future studies should determine whether such balance impairments area an underlying cause of higher post-discharge falls in women.

Older patients undergoing THA/TKA surgery often have comorbidities (e.g., obesity[38]. Obesity is known to be associated with postoperative wound infection, poor functional scores, and limited knee ROM in TKA patients[39]. Obesity may also increase lower limb joint loading and stiffness, and decreased pre-operative function and walking ability that may heighten post-TKA fall risks[16].

Interestingly, patients undergoing THA/TKA in small-sized or rural hospitals are more likely to fall than those staying in larger city hospitals. Although speculative, this observation may be attributed to fewer staff and facilities in small or remote hospitals. Future studies should investigate whether fall prevention education to staff and patients can lower the risk of inpatient post-THA/TKA falls.

Different types of anesthetic techniques are associated with inpatient falls in TKA patients. Neuraxial anesthesia is better than a continuous catheter FNB during surgery in reducing the risk of falls. Since neuraxial anesthesia can decrease intraoperative blood loss, it can minimize the need for intraoperative blood transfusion, which can lower postoperative risk of falls[40]. As anemia and blood loss anemia are common risk factors for falls, the impact of intraoperative neuraxial anesthesia on postoperative falls in TKA patients with anemia should be examined.

Risk factors for post-discharge falls

Medications are commonly used in THA/TKA patients with comorbidities[41], which may lead to fall. For instance, antipsychotics and antidepressants are commonly prescribed to patients with major depression[42]. Antipsychotic drugs may impair balance and gait, whereas antidepressants may disturb sleep and cause daytime drowsiness and confusion, which may increase the risk of falling[43–46]. Physicians should evaluate prescribed medications (especially for psychiatric patients) in the early post-THA/TKA stage and adjust medications types and dosages accordingly[18,31].

Post-THA/TKA patients who live alone may have severe fall consequences because they may have difficulty getting up from the floor unaided after falls[47]. Compared to older patients living with others, those living alone may have more fear of falling, fall history and be less engaged in activities[48], which lead to progressive mobility decline. Accordingly, sufficient rehabilitation (including fall prevention exercises) should be given to these high-risk patients to lower their risk of falls after discharge.

THA patients with a shorter surveillance period or prior TKA may be associated with residual lower limb muscle weakness[18,49], proprioceptive deficits[18,50] and pain[51], which may increase their risk of falls. Post-THA/TKA patients are known to have 30–80% reduction in pre-operative muscle strength in the operated side[52,53]. The functional capacity of post-THA patients may require almost 1 year to recover[54], while some physical limitations (such as the ability to ascend/descend stairs) may persist up to 7 years following TKA[49,51]. Since many joint tissues (including cruciate ligaments and menisci) and associated proprioceptors are resected during total joint arthroplasty procedures[55], the remaining sensory receptors in the operated joint may be insufficient to detect subtle postural disturbances for balance control during daily activities[56]. Additionally, pain may increase fall risk by compromising joint proprioception, muscle activation and balance[51].

Risk of bias assessments

None of the included studies justified their sample sizes. Future research should include sample size estimation to ensure adequate statistical power. Future cross-sectional studies should also document reasons for non-participation so as to facilitate data interpretation.

Clinical implications

The current review has summarized both non-modifiable and modifiable risk factors for post-THA/TKA falls, which can help guide falls prevention strategies. Considering the high prevalence of falls following THA/TKA, routine pre- and post-operative screening of risk factors for falls should be adopted. Clinicians can alert patients with non-modifiable risk factors (e.g., older age, minority race, prior fall history, or previous TKA) regarding their heightened risk of falls, and comprehensively evaluate the presence of other modifiable risk factors so that appropriate multicomponent fall prevention interventions (e.g., patient education, home modification, medication review, safe assistive device, balance training exercise programs, and/or training in fall techniques) can be implemented to reduce the risk and impacts of falls[57]. For patients with modifiable risk factors (e.g., electrolyte/fluid imbalance, coagulopathy, anemia, psychiatric diseases, or depression), clinicians should closely monitor patients' pre- and post-operative physical conditions, and prescribe appropriate drugs to optimize patients' medical conditions. Early postoperative fall prevention programs or progressive physiotherapy should also be prescribed to older patients with suboptimal lower limb strengths and ROM to enhance their physical fitness and balance[32,58]. As community-based falls prevention interventions (e.g., tai chi) are known to be effective for community-dwelling older adults[59,60], future studies should investigate the effectiveness of these interventions in lowering fall risks of post-THA/TKA patients.

The current review has several strengths. First, comprehensive search strategies and relevant risk of bias assessment tools were adopted to identify and evaluate potential studies. Second, there was no limitation for language in order to include relevant papers. Third, this review summarizes various risk factors for inpatient and post-discharge falls based on quality of evidence, which can help clinicians systematically identify high risk patients.

This review has some limitations. First, given the heterogeneity of fall measures in the included studies, diverse risk factors for post-THA/TKA falls were reported. However, since many risk factors were reported in a single study, meta-analyses were only conducted on six risk factors. Accordingly, the GRADE approach was adopted to report various risk factors alongside their respective levels of evidence. Second, some included studies used either patient-reported questionnaires or medical record to determine exposures and falls. Findings from questionnaires might be subject to recall bias[61], while retrospective medical record reviews might be limited by missing data or misclassification of risk factors[17]. Therefore, some risk factors and falls might have been missed. Third, one included study involved postoperative rehabilitation, which might modify fall risk factors and subsequent low fall rates (6.2% and 3.1% at 12- and 24-month post-TKA, respectively)[32]. Fourth, six included studies recruited patients with both primary and revision THA/TKA, which hindered the clarification of whether revision THA/TKA was a risk factor for falls[10,11,17,28,29,33]. Fifth, three studies used univariate analyses to identify fall risk factors without considering potential confounders (e.g., biopsychosocial factors)[16,17,30]. Therefore, their results should be interpreted with caution. Sixth, only six included articles had prospective designs; future prospective studies are warranted to elucidate on the causes of falls in these patients.

Conclusions

Post-THA/TKA patients are at risk of inpatient falls and post-discharge falls within the first postoperative year. Older age (i.e., aged 65 plus years) was a risk factor for both inpatient and post-discharge falls but only had low level of evidence. Based on the moderate level of evidence, postoperative complications or comorbidities such as electrolyte/fluid imbalance, coagulopathy and revision THA/TKA are key risk factors for inpatient falls. Similarly, medications, psychiatric diseases, living alone, prior history of TKA, a history of falls, and female gender are key risk factors for post-discharge falls that showed moderate level of evidence. As these risk factors vary in different settings, clinicians should conduct pre- and post-operative screening to identify these risk factors and implement targeted fall prevention programs to lower the risk or consequences of falls among these patients.

Author contributions

CL & AW were responsible for the conception and design of the research, reviewing articles, analyzing data, interpreting the results of the review, writing and drafting the manuscript, and revision of the article for important intellectual content. WT, SL & KH was responsible for performing the review, interpreting results of the research and revising the manuscript. CHY was responsible for interpreting the results of the review and revision of the article for important intellectual content. All authors read and approved the final version of the manuscript.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplementary data

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