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European Journal of Medical Research (2025) 30:262
https://doi.org/10.1186/s40001-025-02482-x

European Journal
of Medical Research

REVIEW

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Identifying key risk factors for the recurrence of benign paroxysmal positional vertigo following successful canalith repositioning maneuvers: a meta analysis

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Abstract

Background An increasing occurrence trend of benign paroxysmal positional vertigo (BPPV) after successful canalith repositioning maneuvers was observed; however, the risk elements for the occurrence of this disease remain undefined. We aimed to conduct a meta-analysis of BPPV occurrence-associated risk factors reported.

Methods A comprehensive search in MEDLINE, EMBASE, PubMed, Springer, and the Cochrane Library up to March 31, 2024. The meta-analysis was carried out with STATA 16.0. Quality evaluation of the articles was performed with the Newcastle–Ottawa Scales (NOS). Data were pooled by a random-effects model. The meta-analysis was registered at INPLASY (202430045).

Results Seventeen studies with 229 patients were included in the present analysis. The recurrence rate of BPPV after Canalith repositioning procedure (CRP) or Epley maneuver in subjects with hypertension [standardized mean difference (SMD) = 0.88,95% confidence interval (CI) (0.81–0.96), $P = 0.00$], Meniere's disease [SMD = 0.84, 95%CI (0.57–1.10), $P = 0.00$], head trauma [SMD = 0.48, 95%CI (0.34–0.63), $P = 0.00$], diabetes mellitus (DM) [SMD = 0.87, 95%CI (0.80–0.94), $P = 0.00$], advanced age [SMD = 0.18, 95%CI (0.08–0.28), $P = 0.00$], osteoporosis [SMD = 0.32, 95%CI (0.20–0.43), $P = 0.00$], female gender [SMD = 0.53, 95%CI (0.40–0.67), $P = 0.00$], migraine headache [SMD = 0.20, 95%CI (0.06–0.35), $P = 0.01$], and vitamin D deficiency [OR = 0.29, 95%CI (0.18–0.40), $P = 0.00$] were appreciably higher than those in patients without hypertension, Meniere's disease, head trauma, DM, advanced age, osteoporosis, female gender, migraine headache, and vitamin D deficiency.

Conclusion This meta-analysis has identified several significant risk factors associated with the recurrence of BPPV following successful canalith repositioning procedures. These include Meniere's disease, head trauma, diabetes mellitus, migraine headaches, female gender, advanced age, osteoporosis, and vitamin D deficiency.

Keywords Benign paroxysmal positional vertigo, Osteoporosis, Migraine headaches, Canalith repositioning procedure, Risk factors

Introduction

Benign paroxysmal positional vertigo (BPPV) is a common peripheral vertigo in the clinic, which is characterized by transient and recurrent intense vertigo caused by a head position change in gravity direction, accompanied by nystagmus [1]. BPPV usually occurs in middle-aged and older adults, accounting for 20 to 40% of peripheral

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vertigo, and its lifetime prevalence rate is about 2.4% [2]. The main characteristics of BPPV are recurrent, self-limited, transient, and high recurrence rate [3]. BPPV is generally divided into two categories according to etiology: secondary BPPV, has definite or possible causes, such as secondary Meniere's disease, idiopathic sudden deafness, vestibular neuritis, otitis media, and head trauma, among others; primary BPPV (or idiopathic BPPV), the etiology of most diseases is not clear [4]. Patients with head position changes in daily life may experience vertigo, which has a severe impact on their lives and work [5].

Canalith repositioning procedure (CRP) is the most effective method for treating BPPV at present, and its effective rate is about 70%–90% [6]. Numerous studies have suggested the effectiveness of CRP in alleviating BPPV symptoms, with most patients reporting a decrease in dizziness following the therapeutic intervention [7]. However, various studies have confirmed that BPPV symptoms often recur after successful canalith repositioning maneuvers [8, 9]. Published studies showed that there are many factors affecting BPPV recurrence, such as age, sleep disorders, high blood pressure, diabetes, cervical spondylosis, bone mineral density, and among others [10]. How to reduce the recurrence of BPPV is a thorny problem troubling many clinicians. Despite numerous studies exploring the risk factors for BPPV recurrence [11, 12], inconsistencies in the results and a lack of a comprehensive overview have hindered the development of standardized clinical guidelines. There is a need for a synthesis of current evidence to identify consistent risk factors for BPPV recurrence. The present study performed a meta-analysis to investigate several recognized risk elements connected to BPPV after successful CRP or Epley maneuvers and to explore whether they have clinical significance.

Methods

Protocol

The current meta-analysis followed the preferred reporting items for systematic reviews and meta-analysis (PRISMA) protocol. The meta-analysis was registered at INPLASY (International Platform of Registered Systematic Review and Meta-analysis Protocols, 202430045).

Literature searching

We searched for articles on MEDLINE, EMBASE, PubMed, Springer, and the Cochrane Library up to March 31, 2024. A detailed search strategy was developed using a combination of Medical Subject Headings (MeSH) terms and free-text keywords to ensure the retrieval of all relevant studies. The search terms included: "benign paroxysmal positional vertigo," "BPPV," "BPV," "recurrence," "risk factor," "canalith repositioning procedure," "CRP," "hypertension," "osteoporosis," "vitamin D deficiency" "diabetes," "migraine," "Meniere disease," "sudden deafness," and "head trauma." Two independent reviewers carried out the search process and assessed all included articles. Disagreements were determined through discussion.

Selection criteria

The inclusion criteria were employed: (1) Case–control study or cohort study reporting the risk factors for BPPV recurrence; (2) studies that reported OR accompanied by 95% CI to quantify the strength of the association between risk factors and BPPV recurrence; (3) studies with complete data, including the number of recurrent and non-recurrent cases; (4) follow-up period $\geq$6 months. Reviews, case reports, conference abstracts, duplicated studies, and/or studies with insufficient data were excluded from this study.

Data extraction

The following data were extracted by two reviewers (Wen YL, Fan YY): first author, publication year, country, study design, follow-up time, population, sample size (trial/control), outcome indicators, and results. Any inconsistencies were determined by discussion with the third author (Jian BS).

Quality evaluation and publication bias

The NOS was used for the quality evaluation. Two independent authors carried out the quality evaluation. Publication bias was measured by Deeks' funnel plot asymmetry test.

Statistical analysis

The statistical analysis was conducted using STATA 16.0 software. All statistical assumptions, including the normality of the data and the homogeneity of variances, were tested prior to conducting the meta-analysis. These tests helped to validate the appropriateness of the statistical methods used. To handle missing data, we adopted a conservative approach by imputing values where necessary, using the best available data from similar studies or applying established statistical techniques to ensure the integrity of our analysis. The choice of imputation method was based on the nature of the data and the extent of the missing information. A random-effects model was selected for data pooling in the analysis. This model accounts for both between-study and within-study variability, which is particularly relevant when comparing the recurrence rates of BPPV after CRP in diverse patient groups. The random-effects model provides a more conservative estimate of the effect size, reflecting the inherent variability across studies. By employing this model,

we were able to account for the differences in clinical settings, treatment protocols, and patient demographics that contribute to the observed heterogeneity in the data. To further assess heterogeneity within the context of the random-effects model, we calculated the I^2 statistic and the tau-squared (τ^2) value. The I^2 statistic measures the proportion of total variation across studies that is attributable to heterogeneity rather than chance. The τ^2 value represents the estimated true heterogeneity among studies, which is the underlying between-study variance. These measures, along with the Q-test, were used to evaluate the degree of between-study variance. Sensitivity analyses were conducted using a leave-one-out approach to assess the robustness of the pooled estimates. A funnel plot was employed to investigate publication bias, and Deeks' funnel plot asymmetry test was conducted to quantify the potential bias. The combined effects were estimated, and $P<0.05$ was considered statistically significant.

Results

Article selection

Our retrieval strategy obtained 432 articles. Of the 432 potentially appropriate studies, 160 articles were initially disqualified for duplication. After assessing titles and abstracts, 59 articles were disqualified for irrelevance to our purpose. Next, 84 studies were disqualified for the following reasons: no full manuscript accessible, being an inappropriate study design, having a study population aged less than 18 years, and insufficient data. Finally, the full-text assessment generated 17 articles that satisfied the selection criteria; 17 studies were involved in the current meta-analysis. The overview of the article selection is exhibited in Fig. 1, and the features of the 17 involved articles are summed up in Table 1. Our meta-analysis has synthesized evidence from studies that, based on the Newcastle–Ottawa Scales, demonstrate a moderate to high level of quality (Table 1).

BPPV accompanied by hypertension

Three studies have evaluated whether the recurrence of BPPV after successful CRP was associated with hypertension. As indicated in Fig. 2, the recurrence rate of BPPV in patients with hypertension was markedly higher than that in patients without hypertension [SMD = 0.88, 95%CI (0.81–0.96), $P = 0.00$].

BPPV accompanied by DM

Four studies have evaluated whether recurrence of BPPV after reduction was associated with DM. The results showed that the recurrence rate of BPPV in patients with DM was markedly higher than that in patients without DM [SMD = 0.87, 95%CI (0.80–0.94), $P = 0.00$, Fig. 3].

BPPV accompanied by migraine headache

Four studies have evaluated whether the recurrence of BPPV after reduction was associated with migraine headaches. The results showed that the recurrence rate of BPPV in patients with migraine headaches was markedly higher than that in patients without migraine headaches [SMD = 0.20, 95%CI (0.06–0.35), $P = 0.01$, Fig. 4].

BPPV accompanied by Meniere's disease

Four studies have evaluated whether recurrence of BPPV after reduction was associated with Meniere's disease. As exposed in Fig. 5, the recurrence ratio of BPPV in patients with Meniere's disease was considerably higher than that in patients without Meniere's disease [SMD = 0.84, 95%CI (0.57–1.10), $P = 0.00$].

BPPV accompanied by head trauma

Nine studies have assessed whether the recurrence of BPPV after CRP was associated with head trauma. As shown in Fig. 6, the recurrence rate of BPPV after CRP or Epley maneuver in patients with head trauma was considerably higher than that in patients without head trauma [SMD = 0.48, 95%CI (0.34–0.63), $P = 0.00$].

Influence of advanced age on BPPV recurrence

Three studies have evaluated whether the recurrence of BPPV after CRP was associated with advanced age (Fig. 7). The results showed that the recurrence rate of BPPV after CRP or Epley maneuver in patients with advanced age was markedly increased compared with that in younger patients [SMD = 0.18, 95%CI (0.08–0.28), $P = 0.00$].

Influence of female gender on BPPV recurrence

Five studies have evaluated whether the recurrence of BPPV after CRP was associated with female gender (Fig. 8). The results showed that the recurrence rate of BPPV after CRP or Epley maneuver in female patients was markedly increased compared with that in male patients [SMD = 0.53, 95%CI (0.40–0.67), $P = 0.00$].

BPPV accompanied by osteoporosis

Four studies have evaluated whether recurrence of BPPV after reduction was associated with osteoporosis (Fig. 9). The results showed that the recurrence rate of BPPV after CRP or Epley maneuver in patients with osteoporosis was markedly increased compared with that in patients without osteoporosis [SMD = 0.32, 95%CI (0.20–0.43), $P = 0.00$].

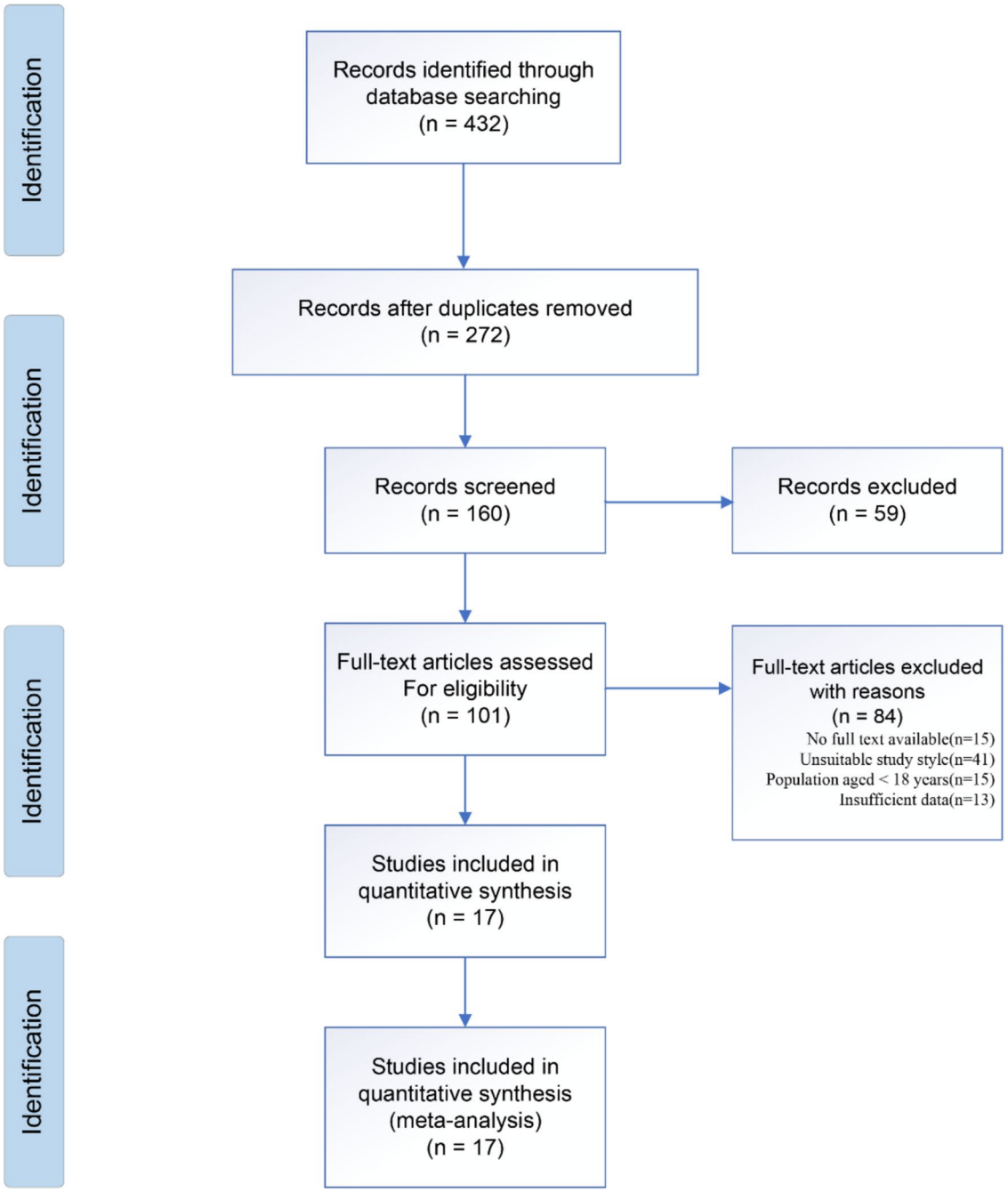

Fig. 1 PRISMA flow illustration

BPPV accompanied by vitamin D deficiency

Three studies have evaluated whether recurrence of BPPV after reduction was associated with vitamin D deficiency (Fig. 10). The results showed that the recurrence rate of BPPV after CRP or Epley maneuver in patients with vitamin D deficiency was markedly increased compared with that in patients without vitamin D deficiency [OR = 0.29, 95%CI (0.18–0.40), $P = 0.00$].

Publication bias

The funnel plots associated with the outcomes displayed significant symmetry (Fig. 11). The significant symmetry in the funnel plots suggests that the dataset is likely free

Table 1 The characteristics of the included articles

Reference	Year	Country	Follow up (months)	Treatment method	Age, year	NOS
Choi et al. [32]	2012	South Korea	> 6	CRP	52 ± 6.9	7
Webster et al. [33]	2015	Brazil	6	Epley Maneuver	N/A	8
Balatsouras et al. [34]	2012	Greece	12	CRP	26–87	8
Babac et al. [35]	2014	Serbia	12	CRP	56 ± 6.7	8
Luryi et al. [36]	2018	USA	36	CRP	64.8 ± 14.6	7
Domhoffer et al. [37]	2000	USA	36	Epley Maneuver	35–83	8
Ogun et al. [38]	2014	USA	6	Epley Maneuver	56.2 ± 13.6	7
Kansu et al. [39]	2010	Turkey	36	CRP	51.9 ± 14.76	6
De Stefano et al. [40]	2014	Italy	24	Epley Maneuver	64–91	7
Tan et al. [41]	2017	China	12	CRP	38–79	8
Su et al. [12]	2016	China	24	CRP	57.7 ± 13.8	8
Del et al. [42]	2004	USA	6–15	Epley Maneuver	64.3 ± 11.3	8
Ahn et al. [43]	2011	South Korea	> 20	CRP	52.8 ± 11.25	7
Picciotti et al. [44]	2016	Italy	12–48	Epley Maneuver	61.9 ± 13.7	7
Song et al. [45]	2015	South Korea	12	CRP	57–83	7
Balatsouras et al. [46]	2017	Greece	> 12	CRP	29–87	8
Casani et al. [15]	2023	Italy	> 36	CRP	10–92	7

NOS Newcastle–Ottawa quality assessment scale, *CRP* Canalith repositioning procedure

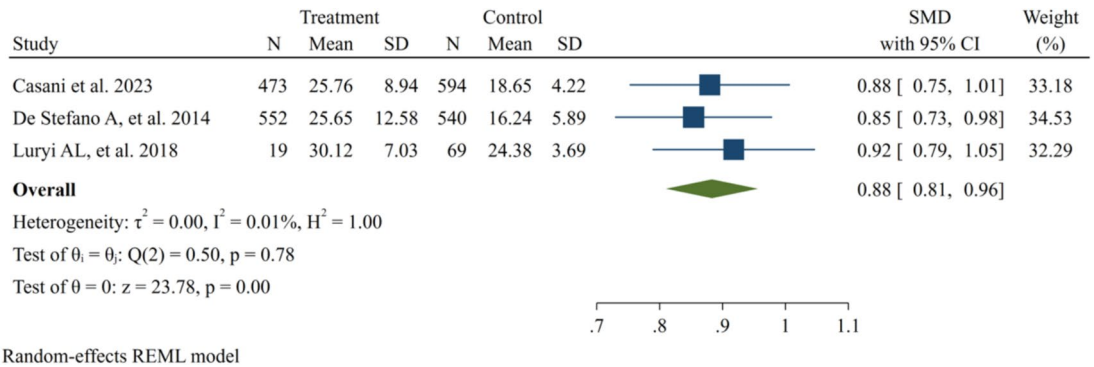

Fig. 2 Forest plot for comparing BPPV recurrence ratio between patients with and without hypertension. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

from significant publication bias, which enhances the validity and reliability of the findings.

Discussion

The current meta-analysis investigated the risk factors associated with the recurrence of BPPV following successful canalith repositioning procedures. Research has suggested that chronic hypertension may lead to widespread vascular damage and atherosclerosis, which can result in injury to the inner ear's blood vessels and the gradual separation of otoliths from the otolithic membrane [13]. Przewoźny and colleagues [14] have proposed that ischemia, a condition associated with hypertension, may contribute to the formation of more otolith residue, necessitating additional treatments to alleviate vertigo. Casani et al. have demonstrated that hypertension is a factor that may increase the likelihood of BPPV recurrence [15]. Our meta-analysis further identified a significant link between the coexistence of hypertension and DM and a higher recurrence rate of BPPV. It is well-established in the literature that DM can lead to neurodegenerative conditions and inner ear ischemia, which may cause otolith shedding and increase the susceptibility to recurrent BPPV episodes [16]. Additional studies have highlighted that patients with both hypertension and DM face a significantly higher risk of BPPV recurrence [17].

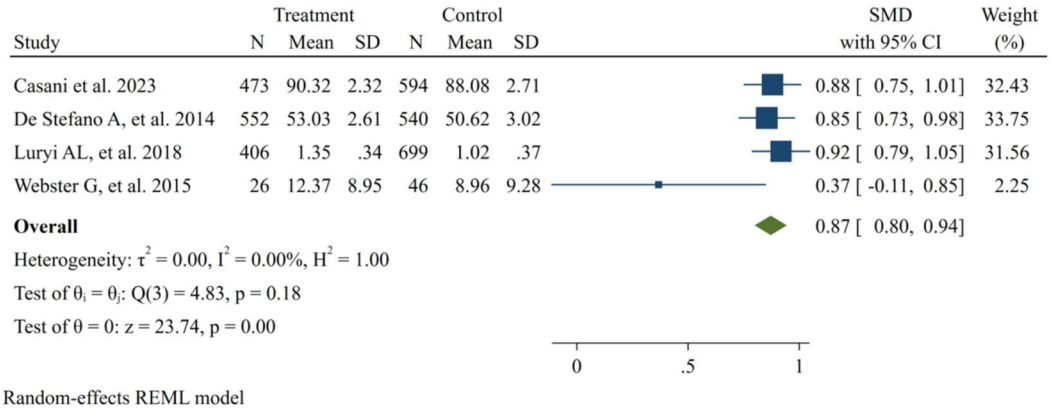

Fig. 3 Forest plot for comparing BPPV recurrence ratio between patients with and without DM. CI, confidence interval. *BPPV* benign paroxysmal positional vertigo

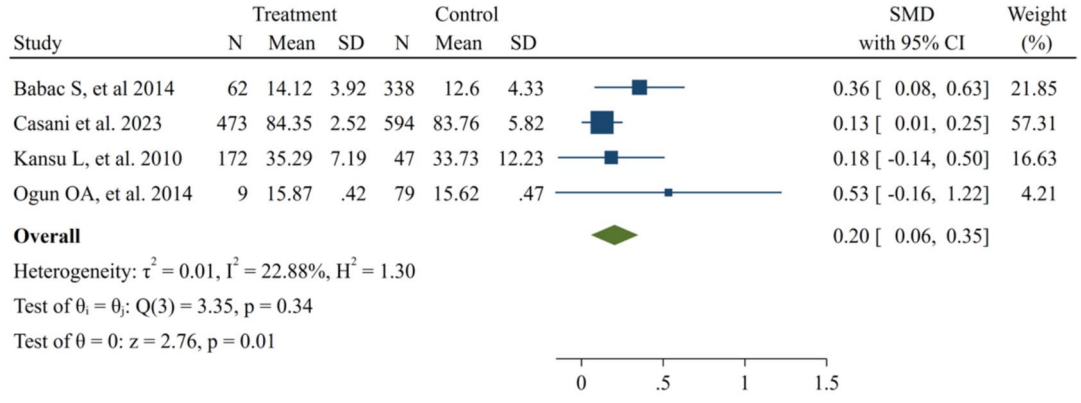

Fig. 4 Forest plot for comparing BPPV recurrence ratio between patients with and without migraine headaches. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

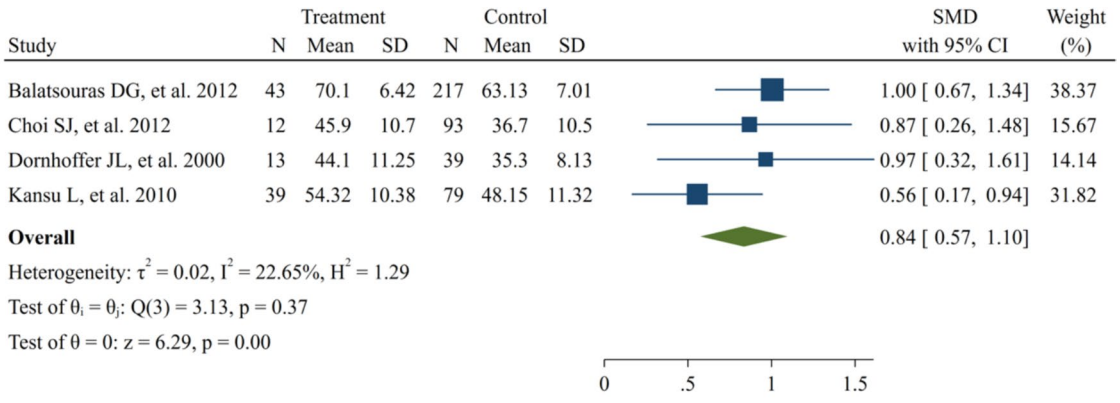

Fig. 5 Forest plot for comparing BPPV recurrence ratio between patients with and without Meniere's disease. *CI* confidence interval

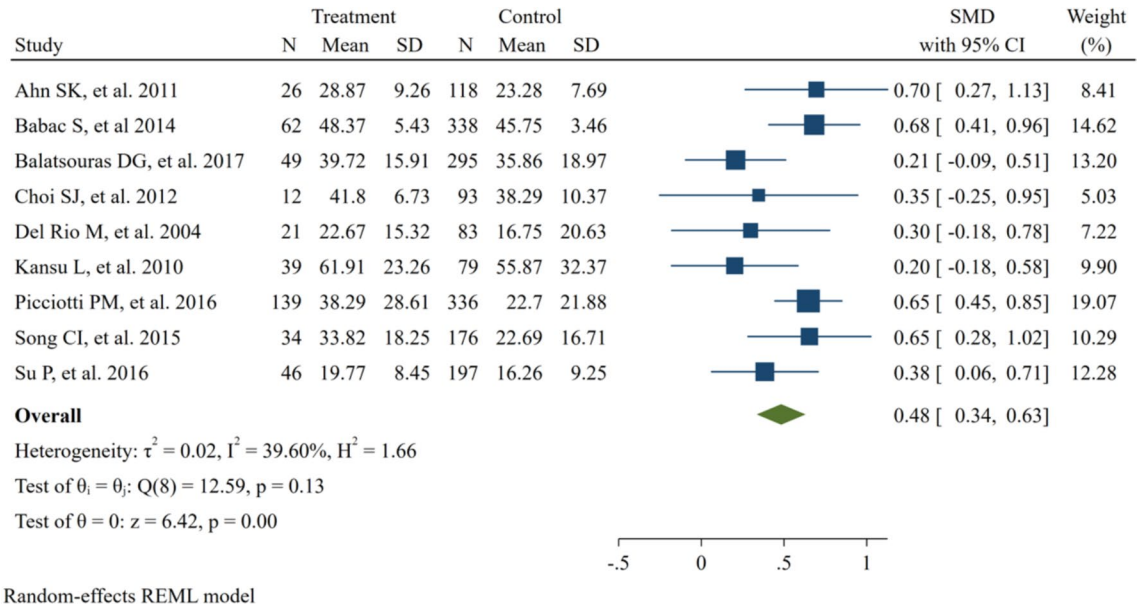

Fig. 6 Forest plot for comparing BPPV recurrence between patients with and without head trauma. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

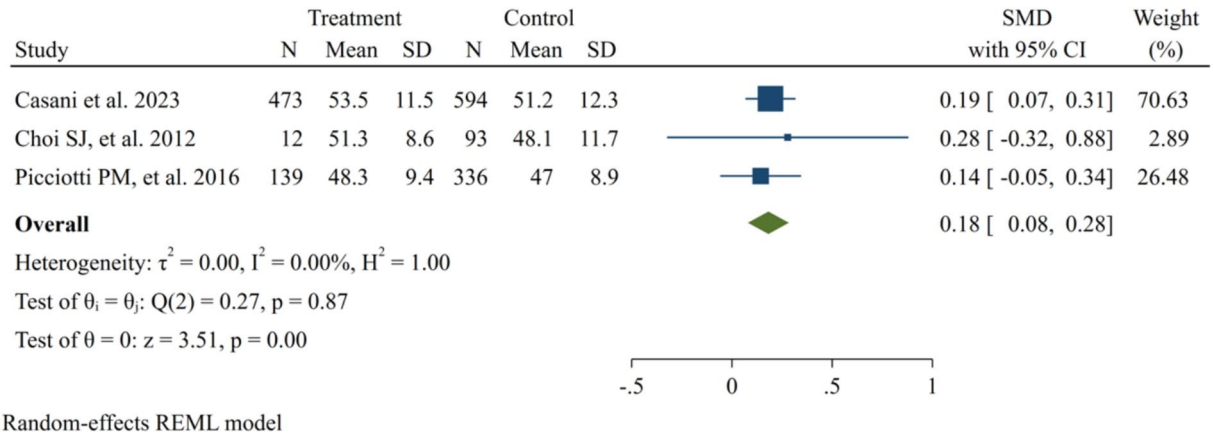

Fig. 7 Forest plot for comparing BPPV recurrence between patients with and without advanced age. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

Earlier work indicated that the ear symptoms of migraine patients may result from vasospasm or ion channel disorder [18]. Ishiyama et al. have also suggested that patients with migraines may play a role in inner ear injury due to repeated vasospasm or vestibular-microvascular disorder, resulting in otolith falling off and entering the semicircular canal, which quickly causes BPPV and persistent BPPV [19]. However, the study of Strupp et al. indicated that there was no marked difference between migraine and BPPV [20]. The direct pathophysiological relationship between BPPV and migraine has not been established. The results of this study showed that the recurrence rate of BPPV in patients with migraine headaches was markedly higher than that in patients without migraine headaches, suggesting that migraine was a critical risk element for BPPV recurrence. Meniere's disease is a common vestibular disease, which is mainly characterized by paroxysmal vertigo, accompanied by fluctuating hearing loss, tinnitus, ear distension, and tightness. Emerging evidence indicates that BPPV, accompanied by Meniere's disease, has an advanced recurrence rate, and requires multiple otolith repositioning. Consistent with this observation, this study has observed that the recurrence rate of BPPV in patients with Meniere's disease was

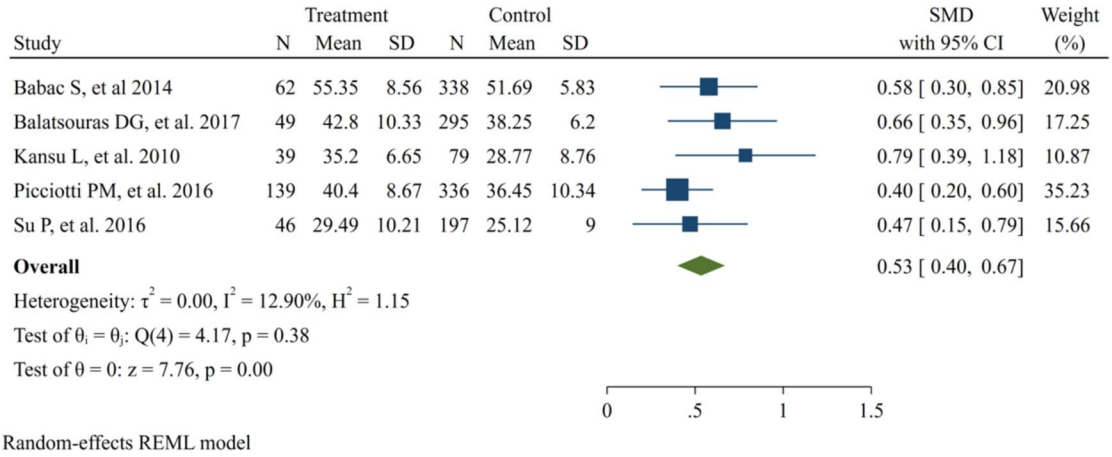

Fig. 8 Forest plot for assessing the influence of female gender on BPPV recurrence. CI, confidence interval. *BPPV* benign paroxysmal positional vertigo

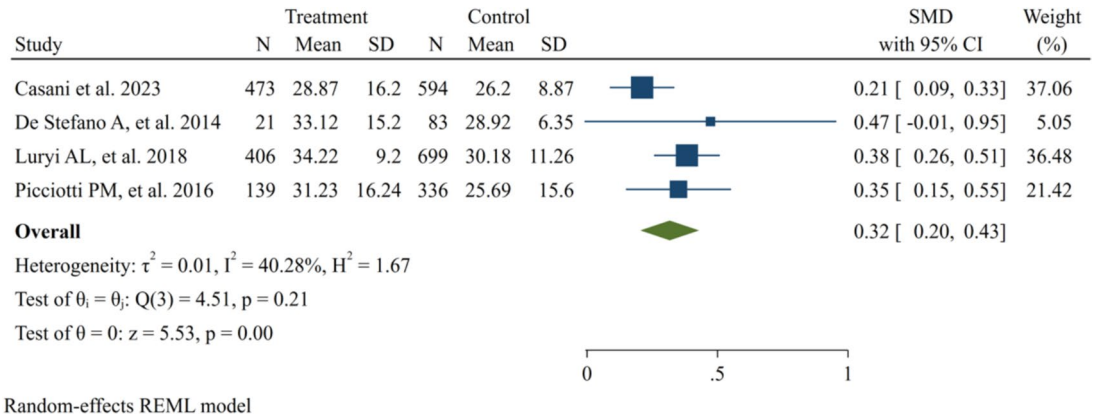

Fig. 9 Forest plot for comparing BPPV recurrence between patients with and without osteoporosis. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

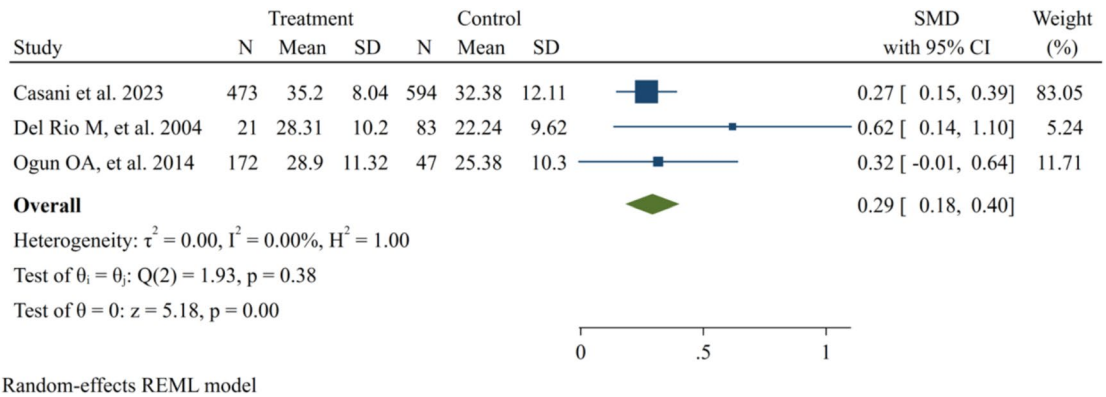

Fig. 10 Forest plot for comparing BPPV recurrence between patients with and without vitamin D deficiency. *CI* confidence interval, *BPPV* benign paroxysmal positional vertigo

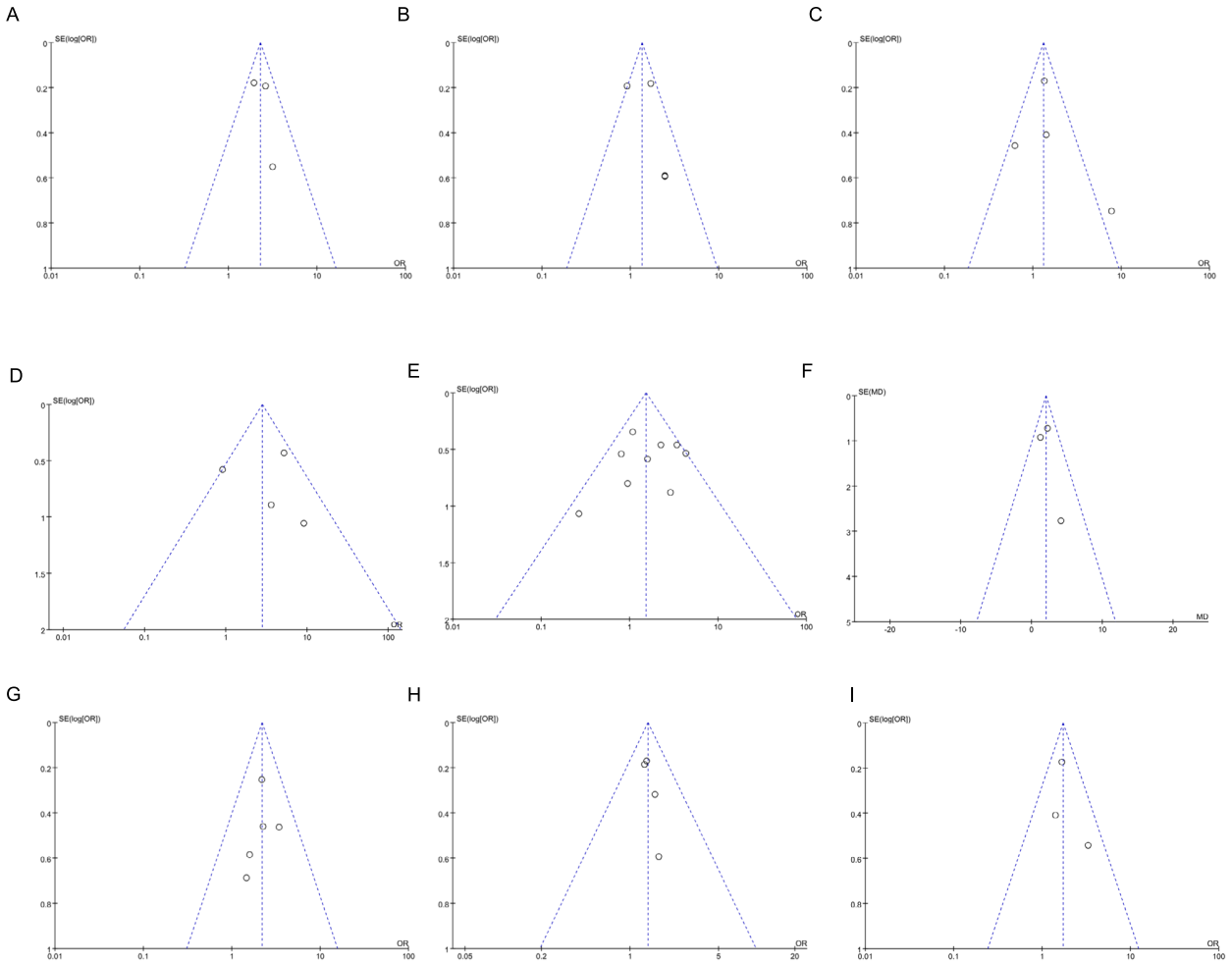

Fig. 11 Analysis of publication bias. **A** publication bias for hypertension; **B** publication bias for DM; **C** publication bias for migraine headache; **D** publication bias for Meniere's disease; **E** publication bias for head trauma; **F** publication bias for advanced age; **G** publication bias for female gender; **H** publication bias for osteoporosis; **I** publication bias for vitamin D deficiency. *DM* Diabetes Mellitus

ominously enhanced compared to that in patients without Meniere's disease, suggesting that Meniere's disease is a risk element for recurrence of BPPV.

Head trauma is a common cause of secondary BPPV. Different natures and degrees of trauma may cause BPPV, such as traffic accidents and blunt head injuries [21]. Remarkably, it has been indicated that head trauma is a common cause of secondary BPPV [22]. Honoré et al. have suggested that head trauma may destroy the otolith membrane, forming post-traumatic BPPV [23]. Jensen et al. observe a high recurrence rate of post-traumatic BPPV, suggesting that the high recurrence of post-traumatic BPPV may be connected to head trauma [24]. This meta-analysis indicated that the recurrence rate of BPPV in patients with head trauma markedly increased, suggesting that head trauma was a risk element for the recurrence of BPPV.

Our meta-analysis also explored the influence of demographic factors on the recurrence of BPPV following canalith repositioning procedures. Regarding the impact of advanced age on BPPV recurrence, our findings revealed a significant association, with a higher recurrence rate observed in older patients. This is consistent with the notion that the aging process may accelerate the degeneration of the vestibular system and reduce cellular regeneration, thus predisposing older individuals to otolith detachment and BPPV recurrence [25]. Furthermore, our meta-analysis confirmed that female gender is a substantial risk factor for BPPV recurrence, with a marked increase in recurrence rates among female patients compared to males. This finding aligns with previous observations of gender disparities in BPPV recurrence, which may be attributed to hormonal or anatomical differences that affect otolith stability and ear function [26]. In addition to demographic factors, our analysis identified that

patients with osteoporosis are at a higher risk of BPPV recurrence after canalith repositioning procedures. Osteoporosis, which affects bone density and integrity, may alter the structure of the otolith membrane, leading to increased otolith detachment and recurrence of BPPV symptoms [27]. The meta-analysis also highlighted the role of vitamin D deficiency in BPPV recurrence. Patients with vitamin D deficiency exhibited a significantly higher recurrence rate of BPPV after treatment. Given that vitamin D is crucial for bone health, its deficiency may contribute to the compromised integrity of the inner ear structures and the subsequent shedding of otoliths [28]. These findings underscore the importance of considering age, gender, and comorbid conditions such as osteoporosis and vitamin D deficiency when assessing the risk of BPPV recurrence.

In this meta-analysis, our findings contribute to the ongoing discourse on the risk factors for BPPV recurrence, particularly within the subset of patients who have undergone successful CRP. The discrepancy observed in the risk factors identified between our study and the studies by Sfakianaki et al. [29], Chen et al. [30], and Li et al. [31] can be attributed to several factors, most notably the difference in study populations. Our study focuses on patients who have experienced a recurrence of BPPV after a successful CRP, which is a specific population with a distinct clinical history and potential risk factors. The inclusion of patients only after a successful CRP allows for a more targeted analysis of the risk factors that contribute to BPPV recurrence in this post-treatment setting. In contrast, the studies by Sfakianaki et al., Chen et al., and Li et al. included a broader population of BPPV patients, some of whom have experienced recurrent episodes before undergoing any treatment, including CRP. This difference in the study population may explain the variations in the identified risk factors. Additionally, the temporal aspect of the risk factor assessment may play a role in the observed differences. Our study evaluates risk factors after a successful CRP, which may influence the risk profile differently than assessments conducted prior to any treatment. Factors such as the duration of follow-up, the definition of recurrence, and the criteria for successful CRP may also contribute to the heterogeneity of the findings across studies.

Our meta-analysis is subject to several key limitations. Firstly, the small sample sizes observed in certain studies included in our analysis may affect the precision of our estimated effect sizes and constrain the generalizability of our results. To mitigate this, we have utilized STATA 16 to conduct a more robust analysis. This approach allows for a more detailed of between-study variance and enhances the reliability of our findings. However, larger-scale research is still needed for validation purposes. Secondly, the paucity of studies incorporated into our analysis may not fully capture the underlying heterogeneity, potentially influencing the accuracy of our assessment. This limited number of studies also diminishes our statistical power, increasing the likelihood of overlooking smaller effect sizes or significant differences. To address these limitations, future research should aim to include a broader array of studies to bolster the reliability of the findings and enhance the statistical robustness of the analysis. Additionally, the retrospective nature of most of the studies introduces inherent biases in data collection and presents challenges in controlling for all potential confounders, which may affect the reliability of the evidence presented. Furthermore, we have identified selection bias, information bias, and confounding as additional sources of potential bias. Despite employing the Newcastle–Ottawa Scale for quality assessment, its scope may not encompass all facets of study quality, thus serving as an additional limitation. Lastly, the observed heterogeneity among studies, likely due to variations in design, populations, and measured outcomes, could influence the meta-analysis results, emphasizing the need for careful interpretation and further investigation. This heterogeneity is partially accounted for by the random-effects model we have used, which allows for the inclusion of between-study variability, but it also underscores the importance of conducting more extensive research to understand the factors contributing to this heterogeneity.

Conclusions

In conclusion, this meta-analysis has identified several factors that may be associated with an increased risk of BPPV recurrence post-canalith repositioning procedures. These include hypertension, diabetes mellitus, advanced age, female gender, vitamin D deficiency, a history of Meniere's disease, osteoporosis, prior head trauma, and, importantly, migraine headaches. The findings underscore the complex interplay of demographic and clinical factors influencing BPPV recurrence. While these factors are indicative of potential recurrence risks, the evidence suggests that the associations may be complex and influenced by a range of variables. Therefore, while our findings point towards possible targets for intervention in high-risk patient populations, they also highlight the need for further research to establish causality and to develop evidence-based strategies that could reduce the incidence of BPPV recurrence and improve patient outcomes.

Acknowledgements
None.

Author contributions
Yanling Wen: Conceptualization, Investigation, Methodology. Yiyan Fan: Conceptualization, Data Curation, Supervision. Baoshan Jian: Data Curation, Methodology, Writing—Original Draft.

Funding
None.

Availability data and materials
The data that support the findings of this study are available in JIANGUOYUN at https://www.jianguoyun.com/p/DY8-5W8QoM6KCxif3dUFIAA.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 5 September 2024 Accepted: 19 March 2025
Published online: 10 April 2025

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