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REVIEW

Prognostic significance of frailty in older patients with hip fracture: a systematic review and meta-analysis

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Abstract

Purpose Hip fracture (HF) has become a major healthcare concern associated with higher mortality in older patients. Frailty is one of the most important problems in aging population but its prognostic value in HF remains susceptible. This systematic review and meta-analysis aimed to evaluate the association between frailty and adverse outcomes in older patients with HF.

Methods We systematically searched electrical databases including PubMed and Embase to find eligible literature with end-search restriction of February 20, 2021. The main endpoints were all-cause mortality, peri-operative complications, abnormal discharge, and length of stay (LOS). Pooled effect size was calculated by random-effects or fixed-effect model according to study heterogeneity. Three subgroup analyses based on follow-up times, study design, and frailty criteria were conducted.

Results We screened 22 studies out of 1599 identified studies in our analysis. Compared with normal patients, frail ones had a higher risk of mortality both before (OR = 3.48, 95% CI: 2.50–4.85, $I^2 = 87.2\%$, $P < 0.001$) and after (OR = 1.87, 95% CI: 1.44–2.44, $I^2 = 85.5\%$, $P < 0.001$) adjustment. The incidence of peri-operative complications, abnormal discharge, and prolonged LOS also significantly increased in frail subjects. There was no publication bias observed and the pooled results were stable based on sensitivity analysis.

Conclusion Overall, more attention needs to be paid to the prognostic effects caused by frailty in seniors with HF. Better understanding of the association between frailty and adverse outcomes in HF could help doctors perform co-management across orthopaedic and geriatric departments.

Keywords Frailty · Hip fracture · Older · Prognosis

Introduction

Hip fracture (HF) is defined as fracture occurring in the area between the edge of the femoral head and 5 cm below the lesser trochanter, and has been confirmed to be associated with high mortality (approximately 7.1% at one month and 30% at one year [1]), morbidity and disability for those who survive [2–4]. It has a high annual incidence of approximately 75,000 (mean age, 83–84), steadily increasing and expected to reach 6.3 million people in 2050 [1, 5]. Established studies have estimated that the total cost of health care for osteoporosis-related HF accounts for over one-third of Asia's gross domestic product (GDP) per capita [6]. HF results in tremendous personal, family, and socioeconomic burdens and has become one of the most important public health problems in the geriatric trauma field.

Frailty, a type of disease or syndrome resulting from decreased multisystem reserve as age increases, comprising either physiological or psychological degeneration, or

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both [7], reflects a more favourable biological age. Frailty has proven to be associated with several adverse outcomes [8], leading to considerable heterogeneity in the prognosis of older patients [9, 10]. Existing studies have demonstrated a strong connection between frailty and a higher incidence of post-operative mortality, complications, and prolonged hospital stays in older patients undergoing elective surgery [10]. However, the value of frailty in the realm of urgent trauma has not been investigated.

Previous studies documented that older patients with HF are at relatively higher risk of being exposed to frailty [11], and some adverse outcomes such as increased mortality, incidence of post-operative complications and reduced physical function can be observed in these geriatric patients. We thus conducted this systematic review and meta-analysis to investigate what prognostic value frailty can bring to older patients with HF, and offer evidence for management optimization.

Materials and methods

Data sources

The protocol used in this systematic review and meta-analysis was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [12] (Supplementary File 1). These meta-analyses have not been previously registered. We used a variety of strategies to identify potentially eligible studies using two electronic databases, PubMed, and Embase, by combining Medical Subject Headings (MeSH) with non-MeSH terms. The search was limited to articles published up to February 20, 2021, with the language restricted to English. The whole search strategy can be found in Supplementary File 2. The query formulation used for PubMed was as follows:

((Hip Fracture[MeSH Terms]) OR (hip fracture[Title/Abstract])) AND ((Frailty[MeSH Terms]) OR (frail*[Title/Abstract])).

Screening and study selection

Two researchers (Bingzi Yan and Wanting Sun) screened the titles and abstracts to determine which articles contained the information of interest. Then, the full texts of these selected studies were independently reviewed by the two investigators to determine their final inclusion. Included studies necessarily met the following criteria: (1) a well-defined cohort study design; (2) patients aged 60 years or older; (3) frailty in older subjects with HF as the main exposure; (4) outcomes of hazard ratio (HR) or odds ratio (OR) with a 95% confidence interval (CI) reported or able be calculated with sufficient information provided in the studies. The exclusion criteria included: (1) reviews, case reports and conference abstracts; (2) studies that reported only quality of life-related outcomes; and (3) studies that used a single element (e.g., low grip strength) as a factor to diagnose frailty.

Data extraction

The information and parameters of interest were extracted from all the included studies by the two investigators independently, including first author, publication date, type of study design, location, population, sample size, frailty criteria, follow-up time, the proportion of frailty/prefrailty, and HR or OR with 95% CI for major outcomes. The main endpoints included all-cause mortality, peri-operative complications (e.g., cardiovascular complications, deep venous thrombosis/pulmonary embolism [DVT/PE], any site of infection, delirium status), and hospitalization time during follow-up. Disagreements were resolved through discussion with an additional reviewer (Qingyu Dou) with professional knowledge of the related fields.

Quality assessment

The quality of the methodology for these studies was independently assessed by the two reviewers independently, with re-evaluation of discrepancies by a third author. We graded the quality of each included document according to the Newcastle–Ottawa Quality Assessment Scale [13]. The scale, which aims to assess selection and attrition bias, grades the study reports based on cohort selection, comparability, and quality of outcomes in terms of 9 parameters. Final scores range from 0 to 9 and the study quality was ranked as follows: good (≥ 8 stars), fair (5–7 stars), and poor (< 5 stars).

Statistical analysis

Adjusted and unadjusted estimates of our analyses were conducted separately. OR and HR with 95% CI were collected as the effect size for the association between frailty and poor outcomes. The fixed-effect or random-effects generic inverse variance method was used to pool the collected data. The chi-square test and I^2 statistics were used to quantify statistical heterogeneity between studies. A randomized effects model was utilized when there was significant heterogeneity between individual studies ($I^2 > 50\%$ or P value < 0.05), while a fixed model was used for otherwise. To explore the source of heterogeneity, we conducted three subgroup analyses based on follow-up time (in-hospital or ≤ 6 months vs. > 6 months), type of study design (retrospective vs. prospective), and frailty criteria (frailty index [FI] and its modified versions vs. clinical frailty score [CFS]). Subgroup analyses were performed if there were at least two studies available in each category. Random-effects

meta-regression analysis was conducted if there were at least ten studies in each subgroup. Publication bias was detected using Egger's tests and funnel plots to determine asymmetry. We conducted sensitivity analyses by omitting each study individually. All of the statistical tests were two-sided and were conducted by STATA 16.0 software, with $P < 0.05$ considered statistically significant.

Results

Search strategy

In total, the initial systematic search of the databases yielded 1599 publications for possible inclusion. After removing duplicates, we examined the titles and abstracts of the remaining articles. All the irrelevant studies, conference abstracts, reviews, or case reports were excluded. Thirty-six studies were chosen for full-text screening, 14 of which were excluded for different reasons when the exclusion criteria were applied. Eventually, 22 studies [14–35] proved eligible for inclusion. There were no further studies to add after thorough inspection of the references. Figure 1 depicts the flowchart of the screening and selection process as well as the detailed reasons for exclusion.

Research characteristics

Table 1 summarizes the baseline characteristics of the 22 studies [14–35]. Each of the included papers reported separate data for single cohort study. Ten of these studies were prospective [14, 16, 18, 21–23, 25, 28, 33, 35] while the remaining 12 were retrospective [14, 17, 19, 20, 24, 26, 27, 29–32, 34]. These cohort studies were conducted in a wide range of regions, including 11 different countries, and two studies were multicenter designs [25, 27]. Patients enrolled in the studies, the majority of whom were over the age of 70, received follow-up during admission or up to 15 years after discharge. Five studies reported the types of HF, namely, femoral neck, intertrochanteric femur, and subtrochanteric fractures [15, 18, 20, 24, 32], while the other 17 papers did not classify the fracture location [14, 16, 17, 19, 21–23, 25–31, 33–35]. The frailty assessment tools were extracted and documented as follows: ten articles used the FI and its modified versions [14, 15, 17, 20, 21, 26, 27, 29, 33, 34], six used the CFS and its modified versions [23–25, 31, 32, 35], and the remaining articles used other scores [16, 18, 19, 22, 28, 30]. Sixteen studies reported a prevalence of frailty ranging from 22.4% to 80.7%, and eight studies reported a prevalence of prefrailty ranging from 6.5 to 47.8%. When frailty was classified into four levels, the lowest level was designated as nonfrailty, the middle two as prefrailty, and the highest level as frailty.

Risk of bias assessment

Quality assessment of the methodology was performed with the Newcastle–Ottawa Quality Assessment Scale. All 22 studies were of relatively high quality in terms of selection, comparability and outcome parameters, with scores ranging from 5 to 9 (mean, 7.4). Eight studies [15, 16, 21, 25, 30, 32, 33, 35] received a good grade, and the remaining 14 [14, 17–20, 22–24, 26–29, 31, 34] were rated as fair (Table 2).

Frailty and adverse outcomes in HF patients

Frailty and all-cause mortality in patients with HF

The association between frailty and all-cause mortality was analyzed using the mortality outcomes with the longest follow-up periods [14, 15, 19, 20, 22, 23, 27–30, 32, 35] reported in 12 studies. Unsurprisingly, frail patients had a significantly higher risk of mortality in comparison than robust patients (OR = 3.70, 95% CI: 2.59–5.28, $I^2 = 88.2\%$, $P < 0.001$). After adjusting for potential confounders, a slightly lower, but still statistically significant risk of mortality was revealed (OR = 1.87, 95% CI: 1.44–2.44, $I^2 = 85.5\%$, $P < 0.001$). The results are illustrated in Fig. 2.

Frailty and peri-operative complications in patients with HF

Six original datasets [16, 18, 19, 24, 27, 29] on any peri-operative complication were analyzed to determine the influence of frailty on post-surgery complications. The risk of any peri-operative complication was significantly increased in frail patients (OR = 3.48; 95% CI: 2.21–5.46; $I^2 = 80.0\%$, $P < 0.001$), and the result remained significant after adjustment (OR = 1.37; 95% CI: 1.15–1.63; $I^2 = 77.4\%$, $P = 0.004$) (Fig. 3a).

Several specific complications were also analyzed including cardiovascular complications, DVT/PE, any-site infection, and delirium. Crude data from three studies [16, 18, 24] showed that HF patients with frailty had a 289% increased risk of cardiovascular complications (OR = 2.89; 95% CI: 1.49–5.62; $I^2 = 0.0\%$, $P = 0.699$), including myocardial infarction, new congestive heart failure, new arrhythmia, and stroke. For DVT/PE, the analysis of two studies [18, 24] demonstrated that frailty tended to increase the risk of DVT/PE by 38% in older frail patients (OR = 1.38; 95% CI: 0.26–7.39; $I^2 = 0.0\%$, $P = 0.571$). Four studies [16, 18, 24, 27] reported the incidence of infections (pneumonia, urinary tract infection, and surgical site infection), and the pooled data showed that the combined OR of any-site infection was 1.97 times higher in frail HF patients (OR = 1.97; 95% CI: 1.56–2.49; $I^2 = 8.6\%$, $P = 0.363$). In the meta-analysis of the raw data from three studies [16, 18, 24] reporting delirium, a significantly increased risk of delirium was found in frail HF patients (OR = 9.07; 95% CI: 5.21–15.78; $I^2 = 22.2\%$, $p = 0.277$).

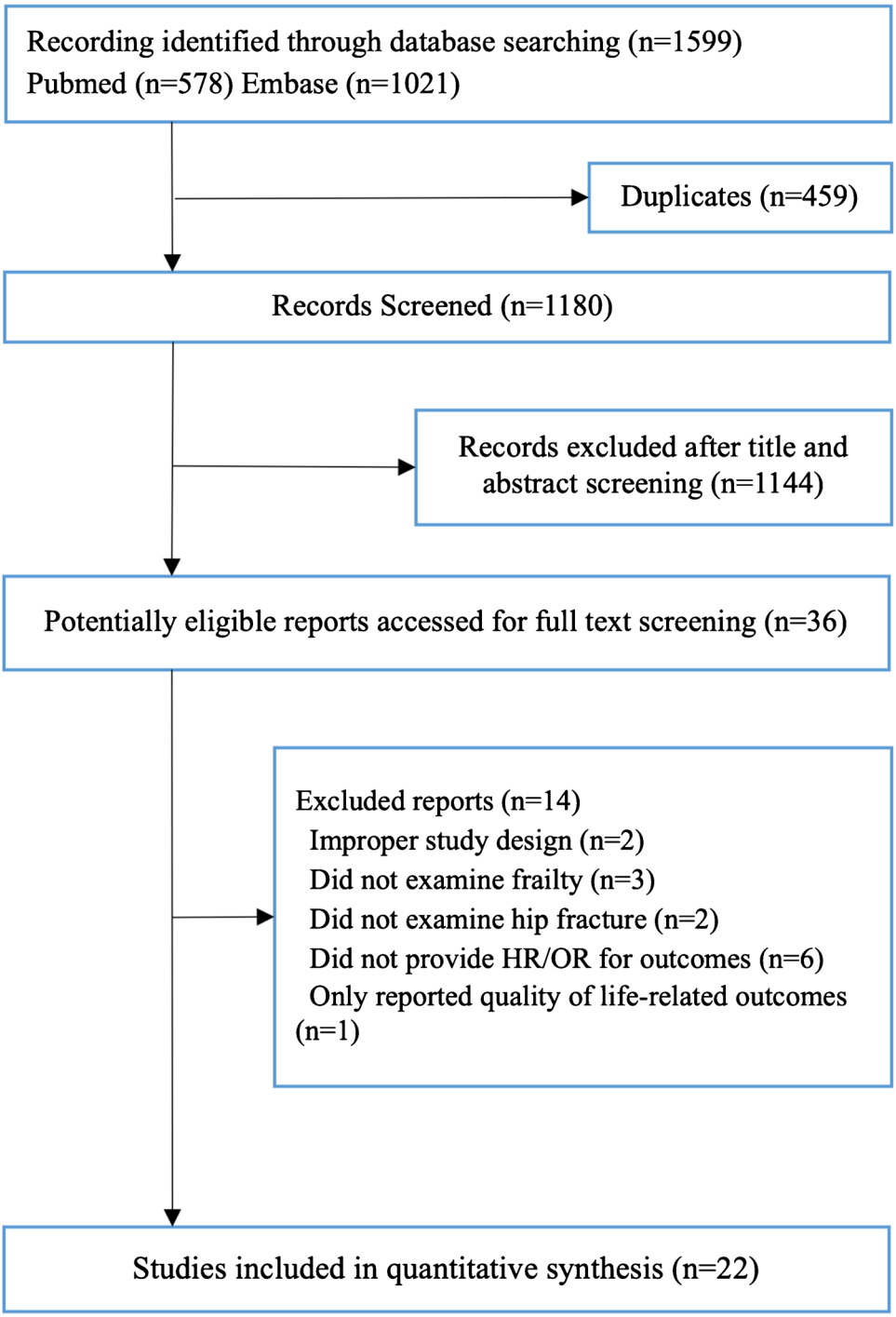

Fig. 1 Flow chart of the selection process

Table 3 illustrates the unadjusted outcomes of the complications mentioned above.

Frailty and abnormal discharge in patients with HF

Abnormal discharge in HF refers to patients who failed to return home after discharge and instead sought care at a nursing home, transitional care facility, or other long-term care center. Five studies [14, 19, 24, 28, 32] were included in a meta-analysis to explore the relationship between frailty and abnormal discharge in HF patients. The risk of abnormal discharge was significantly increased 4.42-fold in frail subjects (OR = 4.42, 95% CI: 1.54–12.69, $I^2 = 93.7\%$, $P < 0.001$) (Fig. 3b).

Frailty and LOS in HF

LOS was defined as the duration of hospitalization in days (d). Two studies [16, 28] recorded prolonged LOS

Table 1 Characteristics of the included studies on the association between frailty and clinical outcomes

Study	Study type	Location	Type of HF	Frailty measure	Age	Sample Size(n)	No. of females	Prevalence (frailty, %)	Prevalence (prefrailty, %)	Follow-up (mo)
Patel 2014	Retrospective	USA	low-energy femoral neck fracture	mFI-19	≥ 60 (mean 81.05)	481	N/A	41.6	N/A	24
Krishnan 2014	Prospective	UK	HF	FI	Mean 81	178	131	36	32.5	180
Kistler 2015	Prospective	USA	HF	FFI	≥ 65	35	29	51	N/A	In-hospital
Dayama 2016	Retrospective	USA	HF	mFI-11	mean77.34 ± 9.8	3121	2183	N/A	N/A	1
Kua 2016	Prospective	Singapore	Femoral neck or intertrochanteric fracture	REFS	≥ 60 (mean 79.1 ± 9.6)	82	55	28	N/A	6
Choi 2017	Retrospective	Korea	HF	MFS	≥ 65	482	343	24.3	N/A	Median 34.6 (19.7–52.4)
Winters 2018	Prospective	Netherlands	HF	VMS	≥ 70 (mean 83)	277	N/A	58	N/A	Median 25
BoissonneAult 2018	Retrospective	USA	intertrochanteric femur fracture	mFI-11	Mean 73	229	111	N/A	N/A	In-hospital
Vasu 2018	Prospective	India	HF	mFI-19	≥ 65	60	26	50	N/A	12
Cornelis 2019	Prospective	Netherlands	HF	GFI	≥ 65	696	490	53.3	N/A	12
Inoue 2019	Retrospective	Japan	HF	mFI-19	≥ 65 (mean 83.7 ± 7.4)	270	218	N/A	N/A	In-hospital
Chan 2019	Retrospective	Canada	Femoral neck, intertrochanteric, subtrochanteric fracture	CFS	≥ 65	422	267	44.3	38.9	In-hospital
Chen 2019	Prospective	Multicenter	HF	CSHA-CFS	mean 78 (53–97)	245	166	22.4	46.1	6
Caliskan 2019	Prospective	Turkey	HF	CFS	> 65	56	44	51.8	39.3	In-hospital
Wilson 2019	Retrospective	USA	HF	mFI-11	Mean 73.65 ± 12.73	377	185	N/A	N/A	In-hospital
Traven 2019	Retrospective	Multicenter	HF	mFI-5	≥ 60 Mean 79	58,603	41,608	80.7	N/A	In-hospital
Jorissen 2020	Retrospective	Australia	HF	FIS	≥ 65 (median 86)	4771	3607	24.8	47.8	≥ 12 Median 62.4
Low 2020	Retrospective	Australia	HF	CFS	≥ 65	844	590	69.9	6.5	In-hospital
Narula 2020	Retrospective	Western Australia	PFF	CFS	Mean 82.7 ± 9.1	509	374	43.4	40.9	12
Pizzonia 2020	Prospective	Italy	HF	mFI-19	≥ 65	364	284	72.5	18.7	Median 2.4 years
Schuijt 2021	Retrospective	USA	HF	FI	≥ 65	313	225	N/A	N/A	In-hospital
Thorne 2021	Prospective	UK	HF	CFS	Median 85 (78–90)	2422	1709	N/A	N/A	36

HF hip fracture, *PFF* proximal femur fracture, *FI* Canadian Study of Health and Aging Frailty Index, *mFI-19* modified Frailty Index based on 19 items of FI, *GFI* Groningen frailty indicator, *FFI* Fried Frailty Index, *FIS* cumulative deficit-based Frailty Index Score, *mFI-11* modified Frailty Index based on 11 items of FI, *MFS* Hip-Multidimensional Frailty Score, *CFS* Clinical Frailty Scale, *VMS* Veiligheids Management System frailty score; *REFS* Reported Edmonton Frail Scale, *CSHA-CFS* Chinese-Canadian Study of Health and Aging Clinical Frailty Scale, *mFI-5* modified Frailty Index based on 5 items of FI, *N/A* not available

in frail subjects with HF, including mean days and standard deviation (SD). Our analysis reported that the difference was statistically significant (weighted mean difference [WMD] = 2.59, 95% CI: 1.82–3.36, $I^2 = 0.0\%$, $P = 0.655$), indicating that the hospitalization time was prolonged in older patients with frailty, as shown in Fig. 3c.

Subgroup analysis and publication bias

For mortality, sufficient data were available to conduct subgroup analyses according to follow-up times, which were categorized as short-term (in-hospital or within six months) or long-term (over 6 months). Overall, when compared to normal participants, both the two subgroups witnessed a significantly raised risk of mortality in the short term (OR = 4.31, 95% CI: 1.83–10.16, $I^2 = 78.1\%$, $P = 0.10$) and long term (OR = 3.02, 95% CI: 1.28–7.12, $I^2 = 94.4\%$, $P < 0.001$) without adjustment. Both retrospective and prospective studies observed increased mortality, with an OR of 3.06 (95% CI 2.14–4.39, $P < 0.001$) in the retrospective group and an OR of 4.08 (95% CI 1.46–11.41, $P < 0.001$) in the prospective group (Table 4). In addition, we carried out subgroup analyses based on different frailty assessment tools, including FI plus its modified versions (5 studies) and CFS (3 studies), and both demonstrated a significantly increased risk of mortality (OR = 3.91, 95% CI: 2.31–6.64, $I^2 = 66.3\%$, $P = 0.016$, vs. OR = 2.03, 95% CI: 0.27–15.20, $I^2 = 90.0\%$, $P < 0.001$). No statistical significance was revealed in the analyses of between-subgroup differences in all pairs (all P values for subgroup difference > 0.05), as shown in Table 4. Meta-regression analysis revealed that the types of cohort study had no effect on the association between frailty and mortality ($P = 0.843$).

Given sufficient data of unadjusted all-cause mortality, no evidence of publication bias was found (Fig. 4). Sensitivity analysis indicated that our pooled data were robust, as shown in Fig. 5.

Discussion

This systematic review and meta-analysis assessed the impact of frailty on the prognosis of older HF patients among 22 studies with relatively high methodological quality. We discovered that frailty is a strong predictor of a variety of unfavourable outcomes following HF, including increased mortality (OR = 1.87, 95% CI: 1.44–2.44, $I^2 = 85.5\%$, adjusted $P < 0.001$), peri-operative complications (OR = 1.37; 95% CI: 1.15–1.63; $I^2 = 77.4\%$, adjusted $P = 0.004$), abnormal discharge(OR = 4.42, 95% CI: 1.54–12.69, $I^2 = 93.7\%$, $P < 0.001$), and prolonged LOS (weighted mean difference[WMD] = 2.59, 95% CI: 1.82–3.36, $I^2 = 0.0\%$, $P = 0.655$).

A previous systematic review revealed that in community-dwelling older adults, the prevalence of frailty and prefrailty were 10.7% and 41.6%, respectively [36]. However, frailty was significantly more prevalent in older HF patients in our meta-analysis, ranging from 22.4% to 80.7%. This is mostly because frailty and HF share several risk factors, including aging, physical inactivity, malnutrition, and a tendency to fall [37]. Furthermore, a tight linkage is established between osteoporosis, the aetiology of HF in older individuals, and sarcopenia, a status of prefrailty. In a previous work recruiting 313 women with hip fracture, the prevalence of sarcopenia and osteoporosis was 58% and 74%, respectively, whereas a sarcopenic woman had a 1.8 times higher risk of developing osteoporosis simultaneously (95% CI: 1.07-3.02) [38]. The concept of "osteosarcopenia," a condition with coexisting progressive osteoporosis and sarcopenia, was firstly proposed by Binkley in 2009 [39]. Osteoporosis and sarcopenia interact with each other via common signaling pathways, including chronic inflammatory conditions (mediated by elevated levels of IL-6, CRP, and TNF-α [40]) and endocrine abnormalities (characterized by decreased hormone levels, e.g., growth hormone (GH) / insulin-like growth factor-1 (IGF-1) [41] and gonadal sex hormones involving estrogen [42] and testosterone [43, 44]). Moreover, the Wnt–b-catenin signal transduction pathway has been shown to mediate bone–muscle interactions by regulating both osteoblastic activity and muscle regeneration [45]. Osteosarcopenia can eventually result in degradation in a wide array of components, including mobility, strength, balance, cognition, motor processing, nutrition,and endurance, all of which are major risk factors for both frailty and HF in older individuals. Osteosarcopenia was prevalent in community-dwelling individuals at a rate of 16.4% in those over 60 years and 33.7% in those over 80 years. Furthermore, osteosarcopenia significantly increased the risk of all-cause mortality by 2.48-fold, the risk of falling by 1.6-fold and the risk of fracture by 1.54-fold [46]. Therefore, the early management of osteoporosis and sarcopenia theoretically plays a pivotal role in the prevention of both HF and frailty [37, 47]. At present, new therapies developed to target bone and muscle are promising, such as selective androgen receptor modulators [48], irisin [49], and cerulenin [50]. A recent real-world study exploring the long-term effectiveness of traditional osteoporotic drugs found that denosumab had a potential dual role as an anti-bone resorptive and muscle-strength-specific cure for osteosarcopenia, providing new insights for treating both HF and frailty [51].

According to our study, frailty increased cardiovascular complications and thromboembolic events in older HF patients. Since these patients have a higher risk of bleeding as a result of comorbidities and declined liver and renal function [52], nonpharmacological approaches combined with physical prevention strategies should be integrated into routine care in addition to individualizing

Table 2 Newcastle–Ottawa Score for the included studies

Study	Selection				Comparability		Outcome			Total
Patel 2014	1	1	1	0	1	1	1	1	1	8
Krishnan 2014	0	1	1	1	1	1	0	1	1	7
Kistler2015	1	1	1	1	1	1	1	1	1	9
Dayama 2016	1	1	1	0	1	1	1	0	0	6
Kua 2016	1	1	1	0	1	1	0	1	1	7
Choi 2017	1	1	1	0	1	1	0	1	1	7
Winters 2018	0	1	1	1	1	1	0	1	1	7
BoissonneAult 2018	1	1	1	0	1	1	1	0	1	7
Vasu 2018	1	1	1	1	1	1	1	1	1	9
Cornelis 2019	1	0	1	1	1	1	0	1	1	7
Inoue 2019	1	1	1	0	1	0	0	0	1	5
Chan 2019	0	1	1	0	1	1	0	1	1	6
Chen 2019	1	1	1	1	1	1	1	1	1	9
Caliskan 2019	0	1	1	1	1	1	1	0	1	7
Wilson 2019	1	1	1	0	1	1	1	0	1	7
Traven 2019	1	1	1	0	1	1	1	0	1	7
Jorissen 2020	1	1	1	0	1	1	1	1	1	8
Low 2020	0	1	1	0	1	1	1	0	1	6
Narula 2020	1	1	1	0	1	1	1	1	1	8
Pizzonia 2021	1	1	1	1	1	1	1	1	1	9
Schuijt 2021	1	1	1	0	1	1	1	0	1	7
Thorne 2021	1	1	1	1	1	1	1	1	1	9

anticoagulation therapy [53]. Fundamental measures include standardizing the use of tourniquets, encouraging early mobilization and post-operative elevation to prevent deep venous backflow disorder, and moderating fluid replacement to avoid dehydration [54, 55]. Several physical intervention facilities such as venous foot pumps (VFPs) [56], and intermittent pneumatic compression devices (IPCDs) [57], should also be widely utilized. For a higher risk of infection associated with frailty, sputum induction with aerosol therapy plus conventional measures (e.g., postural drainage, vibratory excretion) and early removal of urinary catheters have been shown to be effective in improving mucociliary clearance and preventing pneumonia or catheter-related infection [58, 59]. It is worth noting that frailty dramatically increased the incidence of delirium in older adults with HF by 9.07-fold. Delirium has a high prevalence following serious trauma and often causes extended inpatient stay, increased risk of mortality or second fall, and increased care costs [60, 61]. For older frail patients with HF, early assessment and management of risk factors for delirium are top priorities. Established studies have demonstrated that sedative drugs, especially benzodiazepines, may contribute to post-operative delirium, and thus should be eliminated [62]. Other sedative drugs, such as opioids, dihydropyridines, and antihistamine H1 antagonists, should be used with caution after weighing the benefit of managing severe pain against the probability of triggering drug-related delirium [63]. Moreover, a multicomponent intervention protocol with nonpharmacological interventions targeting multiple risk factors for post-operative delirium has been confirmed to be effective, including a reduction in physical constraints, volume and nutrition replenishment, pain management, reorientation, and visual and auditory deficit cure [64, 65]. The high prevalence of frailty and post-operative delirium in older patients with HF poses a serious challenge for orthopaedics. Considering the multidimensional needs of frail elderly individuals, comanagement carried out by surgeons and geriatricians should be implemented to develop a tailored therapeutic protocol. Studies have recorded a higher probability of improved clinical indicators in frail HF older patients undergoing orthogeriatric comanagement (OGC) programs than those who do not, including shorter LOS (regression coefficient = −1.08, SE = 0.54, $p = 0.045$) and lower one year mortality (OR = 0.31, 95% CI: 0.10–0.96) [66], and an increase from 56.8 to 72.7% in patients returning to their source of admission [67].

Guidelines have proposed that older HF patients should receive corrective surgery within 36–48 hours of sustaining a hip fracture [68–70]. The HIP ATTACK (hip fracture accelerated surgical treatment and care track) RCT reported that accelerated surgery (within a goal of 6 h after diagnosis) did not improve either mortality or nonfatal major complications. Accelerated surgery significantly reduced both the prevalence of post-operative delirium (9% vs. 12%, HR 0.72, 95% CI 0.58–0.92, $p = 0.0089$) and length of inpatient stay, and improved the speed of post-operative mobilization [71]. OGC is also able to help shorten pre-operative wait times [72], increasing the proportion of patients who underwent surgery within 48 h (RR = 2.7, 95% CI: 2.4–3.0; $p < 0.0001$) [73].

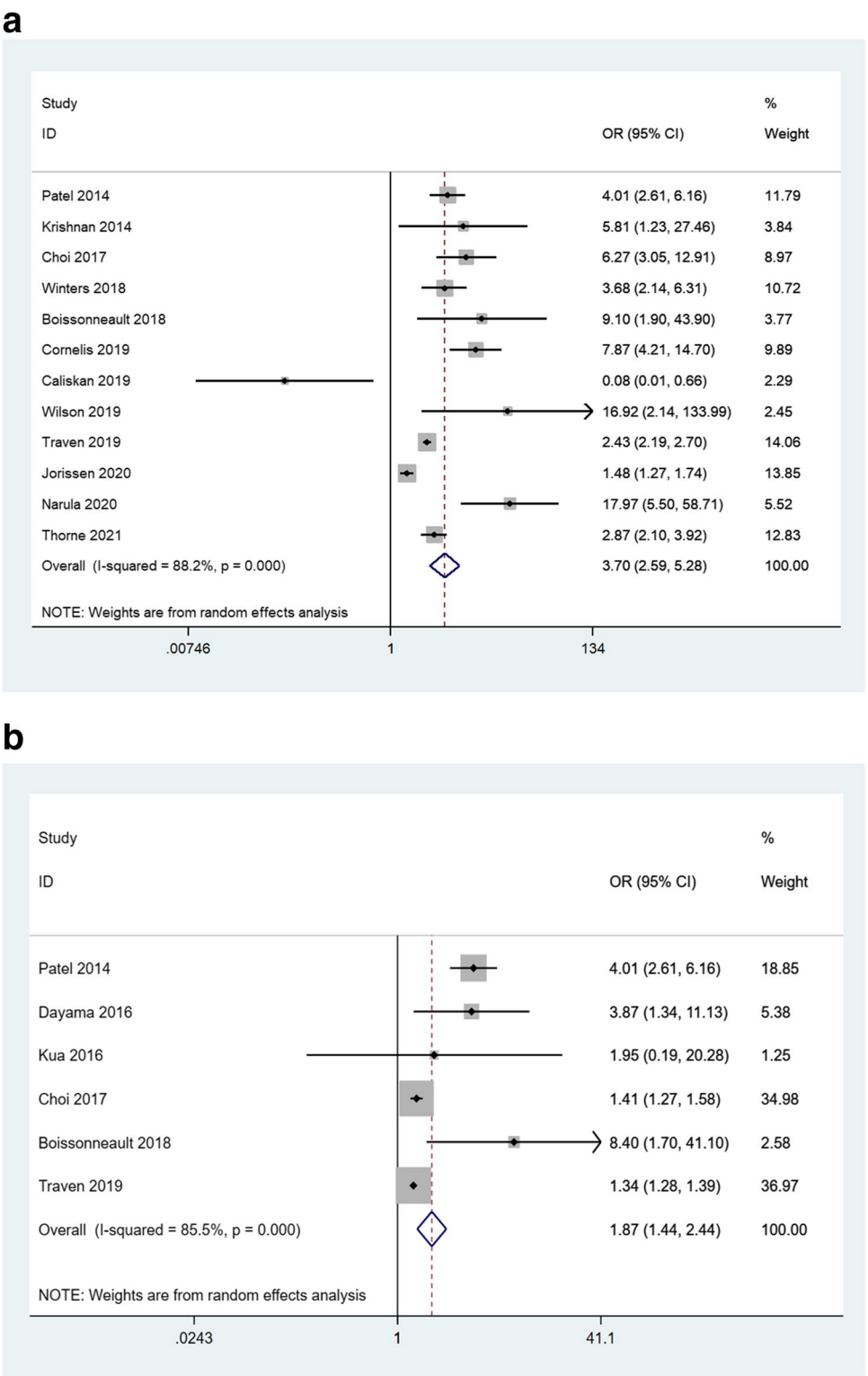

Fig. 2 Association between frailty and all-cause mortality in older patients with hip fracture: **a** unadjusted all-cause mortality during the following-ups; **b** adjusted all-cause mortality during the following-ups

However, for those patients who are the frailest with a limited life expectancy, it is particularly vital to decide whether to undergo surgery because their requires are more focused on promoting comfort rather than extending life. A recent study conducted by Loggers has proved that adverse events were less frequent in frail proximal femoral fracture patients treated non-operatively but instead of operatively [74]. The health-related quality of life in non-operative management group was not inferior to that in patients who received surgical treatment. Frailty assessment not only serves to help build

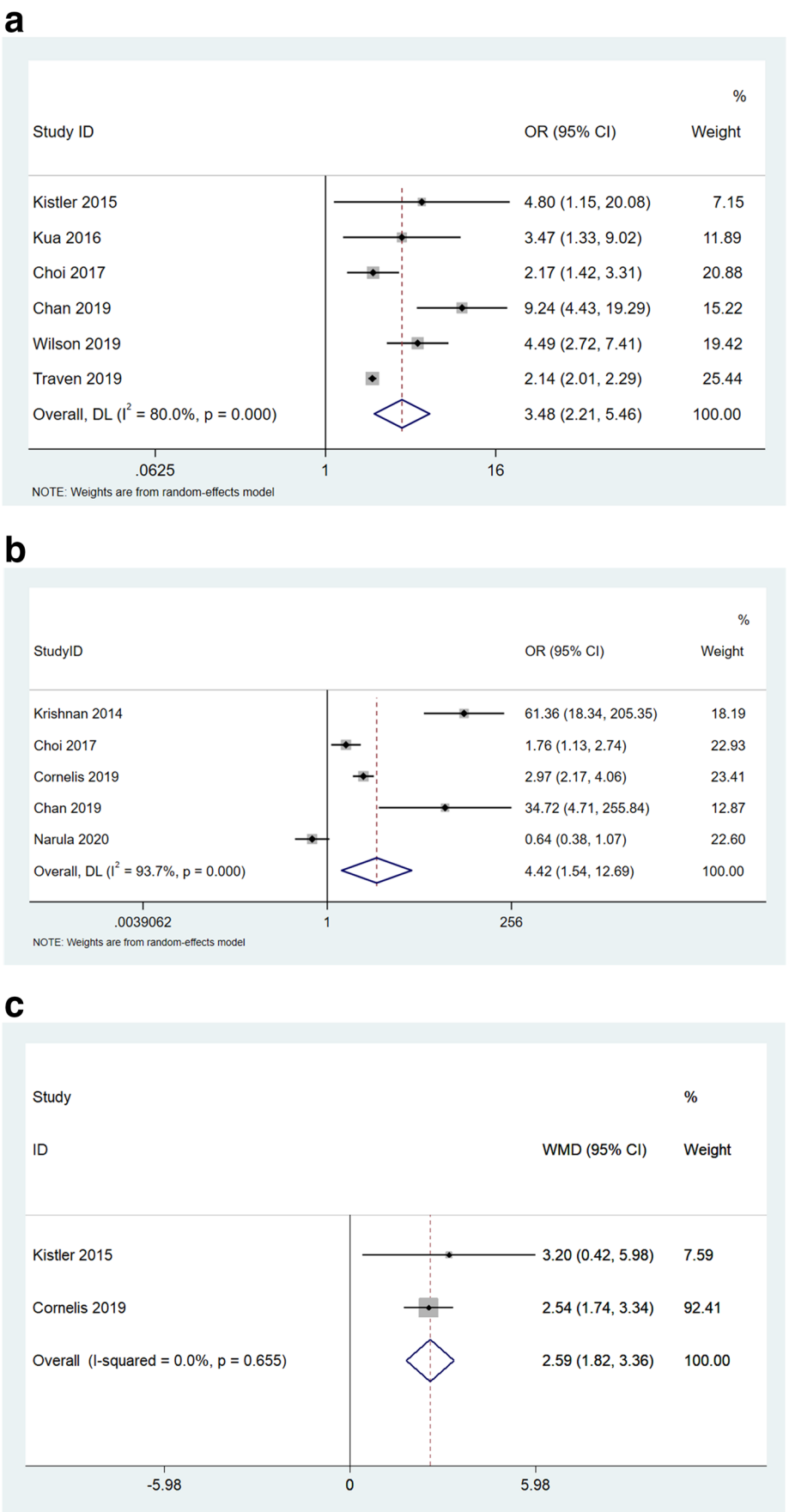

Fig. 3 Association between frailty and any peri-operative complication, abnormal discharge and length of stay (LOS) in older patients with hip fracture: **a** unadjusted any peri-operative complication during the following-ups; **b** unadjusted abnormal discharge during the following-ups; **c** unadjusted LOS during the following-ups

Table 3 Unadjusted peri-operative complications in hip fracture patients during follow-ups

Outcomes	No. of Studies	Events/total		Unadjusted OR (95% CI)	I^2	*P* value
		Frailty	Control			
Any complication	6	8696/42075	1414/11992	3.48 (2.21, 5.46)	80.0%	< 0.001
Cardiovascular complication	3	66/233	12/142	2.89 (1.49, 5.62)	0.0%	0.699
DVT/PE	2	5/215	2/125	1.38 (0.26, 7.39)	0.0%	0.571
Any infection	4	531/42084	86/11624	1.97 (1.56, 2.49)	8.6%	0.363
Delirium	3	170/233	27/142	9.07 (5.21, 15.78)	22.2%	0.277

Any infection: including pneumonia, urinary tract infection, hip wound infection, and surgical site infections

Cardiovascular complication: including myocardial infarction, new congestive heart failure new arrhythmia, and stroke

DVT deep venous thrombosis, *PE* pulmonary embolism

Table 4 Subgroup analyses of unadjusted all-cause mortality according to follow-up time and cohort study types

Subgroup	No. of studies	Unadjusted OR (95% CI)	I^2	*P* value	*P* for subgroup difference
Follow-up time					
≤ 6 months	3	4.31 (1.83, 10.16)	78.1%	0.010	0.44
> 6 months	3	3.02 (1.28, 7.12)	94.4%	< 0.001	
Study design					
Retrospective	7	3.06 (2.14, 4.39)	88.6%	< 0.001	0.32
Prospective	5	4.08 (1.46, 11.41)	82.0%	< 0.001	
Frailty score					
FI*	5	3.91 (2.31, 6.64)	66.3%	0.018	0.32
CFS	3	2.03 (0.27, 15.20)	90.0%	< 0.001	

*FI** Frailty Index and its modified versions, *CFS* Clinical Frailty Scale

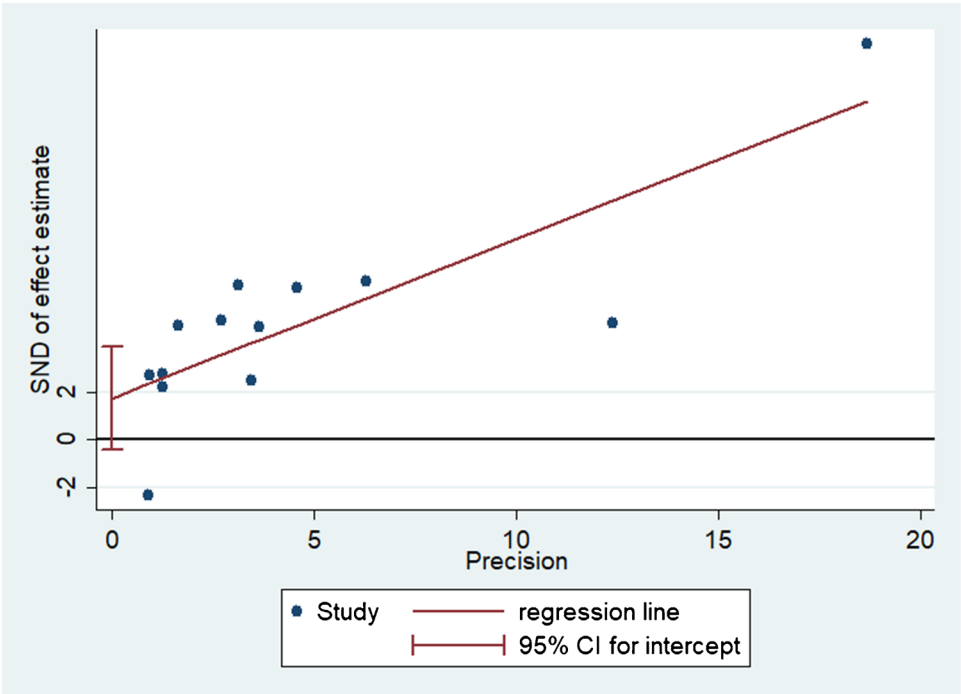

Fig. 4 Publication bias of studies included in the meta-analysis for unadjusted all-cause mortality

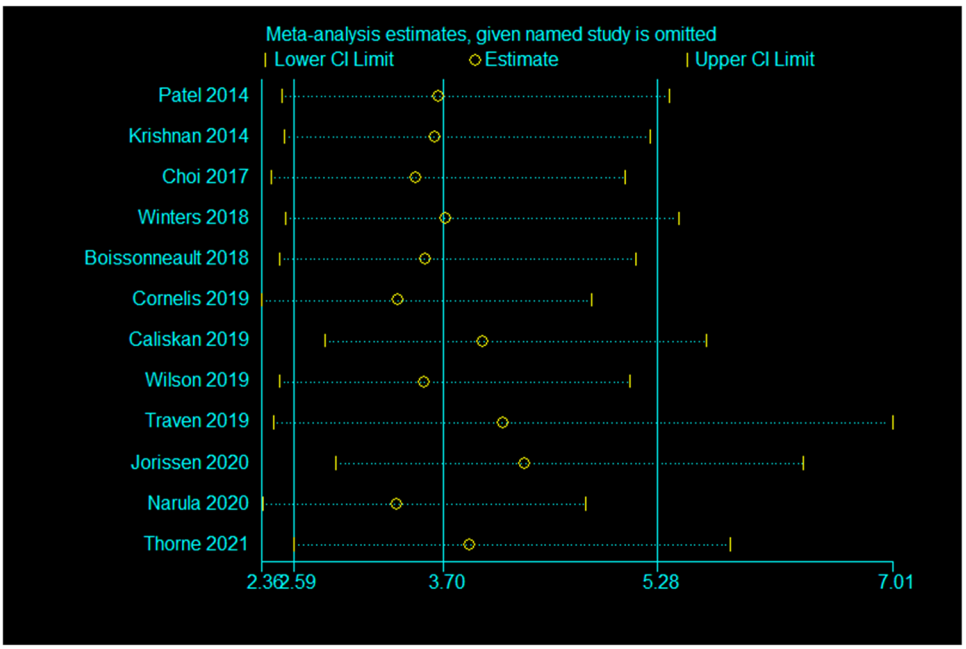

Fig. 5 Sensitivity analyses of the impact of individual studies included in the meta-analysis for unadjusted all-cause mortality

an individualized care plan, but also helps to make treatment decisions between operative and non-operative management for older HF patients. To avoid overtreatment and provide person-centered care, a shared decision-making process involving caregivers, patients and their families should be implemented with a full-scale forecast of the outcomes of non-operative and operative management [75, 76].

Limitation

Some limitations lying in our study are as follows. First, although some studies included in this meta-analysis contain functional parameters, such as activity of daily living (ADL) or quality of life, the nonuniformity of functional measurements made it difficult to calculate the pooled outcome. Second, we failed to conduct a subgroup analysis based on HF types due to insufficient information. It is necessary to investigate whether specific HF types influence the prognostic value of frailty. Finally, the wide variety of frailty assessment tools may be a source of heterogeneity in this meta-analysis, although the subgroup analyses for two such tools showed no statistical significance. Future studies should make the diagnosis of frailty more precise so that this cohort of patients could be applied to individualized orthogeriatric management.

Conclusion

Based on 22 articles, our meta-analysis clearly shows that overall, frailty tremendously increased the risk of adverse outcomes in older adults with HF, especially mortality and delirium. Early management of osteoporosis and sarcopenia as well as multiple fall prevention strategies may play a pivotal role in the intervention of both HF and frailty. Frailty identification should be integrated into consideration pre-operatively with rationally shared decision-making between patients, families and orthogeriatric team to make appropriate treatment plans with informed prognostic risks. Orthogeriatric care models should be widely applied, and more prospective research concerning the validity of orthogeriatric comanagement regarding both frailty and HF as therapeutic targets is required.

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Author contribution BZY designed this study, screened and selected studies for inclusion, extracted data, performed meta-analyses and drafted the manuscript; WTS performed study selection according to criteria, data extraction, meta-analyses and manuscript writing; WW, JHW and GLW evaluated the methodological quality of the included studies; QYD assisted with the study design, results confirmation and manuscript composition, as well as offered advanced professional information in relevant disciplines. The final manuscript has been read critically and approved by all the authors critically.

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Data availability All data generated or analyzed during this study are included in this published article and supplementary files.

Declarations

Ethics approval Not applicable.

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Consent of publication Not applicable.

Competing interests The authors declare no competing interests.

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