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Review Article

Prevalence and Risk Factors of Postdialysis Fatigue in Patients Under Maintenance Hemodialysis: A Systematic Review and Meta-Analysis

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SUMMARY

Purpose: Despite the high prevalence of postdialysis fatigue (PDF) in maintenance hemodialysis patients, no meta-analysis on the prevalence and risk factors of PDF has yet been published. This study aimed to identify the prevalence of PDF and explore its related factors.

Methods: PubMed, Embase, CENTRAL, Web of Science, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the four Chinese databases (National Knowledge Infrastructure [CNKI], Chinese Biomedical Literature database [SinoMed], Wanfang Digital Periodicals [WANFANG], and Chinese Science and Technology Periodicals [VIP] database) were searched from inception up to July 2022. This study was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. The articles were independently searched by two reviewers, and the relevant data were extracted. The Agency for Healthcare Research and Quality was used to assess the quality of the included studies.

Results: Thirteen articles with 2,118 participants were included. The pooled prevalence was 60.0%. The meta-analysis results revealed that the ultrafiltration volume, mean arterial pressure after dialysis, and good sleep quality were potentially associated with PDF, whereas only good sleep quality (odds ratio 0.24, 95% confidence interval 0.19–0.30) was significantly associated with PDF.

Conclusion: PDF is common in maintenance hemodialysis patients, which is related to the ultrafiltration volume, sleep quality, and mean arterial pressure after dialysis. However, the mechanism underlying the risk factors and PDF remains unknown. Further research is warranted to investigate the risk factors, intervention, treatment, and mechanism in maintenance hemodialysis patients.

Introduction

End-stage renal disease (ESRD) refers to the inability of the kidneys to maintain fluid, electrolyte, and waste balance in the body and is a major public health challenge around the world [1]. More than 2 million patients with ESRD require dialysis to survive [2], and maintenance hemodialysis (MHD) is the main method of renal replacement therapy. One of the most frequent side effects of MHD is postdialysis fatigue (PDF). PDF is defined as a feeling of exhaustion requiring rest or sleep for relief [3]. Patients with PDF may need more than 2 hours of sleep or rest to recuperate from dialysis [4], hindering the treatment compliance of dialysis patients. It is a pervasive and debilitating condition that adversely affects the quality of life [5]. In addition, PDF may be associated with functional disability, cardiac ischemia occurrence, and an increased risk of mortality [6,7]. Chronic fatigue (not specified as PDF) may be a contributing factor to cardiovascular events and overall mortality [8,9]. Although chronic fatigue is associated with a high rate of morbidity and mortality among patients with ESRD, prevalence and risk factors for PDF have not been identified yet.

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The prevalence of PDF ranges between 42.9% and 80.0% [10,11]. Several factors may explain the variation in PDF prevalence. First of all, various scales are used to evaluate the symptoms and severity of PDF, such as the revised Piper fatigue scale (RPFS), Chalder fatigue questionnaire, postdialysis fatigue self-assessment scale (PDF scale), and self-designed questionnaires based on time, frequency, and intensity. Therefore, the sensitivity and specificity of the scales are different. Second, methodological differences, such as sampling strategy, may affect the estimates of prevalence. In addition, PDF is considered to be chronic fatigue by health care providers, which may be a key point in explaining the lack of attention in hospitals. Moreover, the lack of acknowledgment of the risk factors of PDF may be attributed to the lack of awareness of this symptom, and some risk factors for PDF remain contradictory. For example, the study by Wang et al. supported an association between PDF and C-reactive protein [12], whereas others did not [13]. Zeng et al. reported an association between PDF and mean arterial pressure after dialysis [13], which was contradicted by another study [14]. Meanwhile, ultrafiltration volume, serum sodium, lactic acid, and dialysis complications were also found to be associated with PDF, but the results are discrepant and inconclusive.

There is no worldwide consensus regarding the prevalence and risk factors of PDF. A previous summarized the estimated prevalence of PDF at 51.0–86.0% [15], but only included three articles without quantitative analysis. Therefore, a systematic review and meta-analysis were performed to synthesize the prevalence and risk factors of PDF to provide better guidance to health care workers.

Methods

Design

The review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. The detailed study protocol can be found on the PROSPERO website under the registration number CRD42022309395.

Search methods

Nine databases were comprehensively searched from inception to July 2022, including PubMed, Embase, CENTRAL, Web of Science, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the four Chinese databases (National Knowledge Infrastructure [CNKI], Chinese Biomedical Literatures database [SinoMed], Wanfang Digital Periodicals [WANFANG] and Chinese Science and Technology Periodicals [VIP] database). Combinations of MeSH terms, Emtree synonyms, and free words were used in the literature search. The search terms comprised kidney failure, hemodialysis, renal dialysis, blood dialysis, blood purification, dialysis, maintenance hemodialysis, maintained hemodialysis, MHD, continuous renal replacement therapy, extracorporeal dialysis, fatigue, weary, exhausted, and PDF. Furthermore, no restrictions were placed on the date, country, publication status, or year of publication, but the languages were restricted to English and Chinese. The details of the search strategy are outlined in Appendix 1. In addition, grey literature and the reference lists included in the identified articles were manually searched.

Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) observational studies; (2) study subjects were adult patients receiving MHD with dialysis duration of more than 3 months, as most of the symptoms of ESRD have been treated and alleviated, to rule out the influence of chronic fatigue state caused by ESRD; (3) specific diagnostic criteria for detecting PDF were available (including scales or dialysis recovery time [DRT]); (4) prevalence or risk factors of PDF were reported. The exclusion criteria were as follows: (1) the studies were not published in English or Chinese language; (2) duplicate studies; (3) no eligible data for extraction; and (4) low-quality studies.

Quality appraisal

Two reviewers (Y.Q. and W.C.X.) independently identified the relevant studies, and any discrepancy relating to the quality of studies was resolved by a third reviewer (B.D.X. or G.J.). The tool of the National Center for Biotechnology Information (US), recommended by the Agency for Healthcare Research and Quality (AHRQ), was used to evaluate the quality of the included studies. The AHRQ includes a total of 11 items with the options “Yes (1 point),” “No (0 point),” and “Unclear (0 point).” According to the score, 0–3 points are regarded as low quality, 4–7 points indicate medium quality, and 8–11 points are considered high quality [16].

Study selection and data extraction

Strictly following the inclusion and exclusion criteria, two reviewers (Y.Q. and W.C.X.) retrieved and reviewed full-text articles after scrutinizing the titles and abstracts of all articles independently. Every article was independently evaluated by the two reviewers for inclusion in this systematic review and meta-analysis. Any discrepancies relating to article inclusion were resolved by discussion with a third reviewer (B.D.X. or G.J.) to reach a consensus. Data extraction was also performed by two independent reviewers (Y.Q. and W.C.X.). The data from the studies included in the systematic review were the name of the first author, publication year, survey time, country, sample size, age of participants, duration of dialysis, diagnostic criteria, prevalence of PDF, and risk factors.

Synthesis

Stata 15.0 software (Stata Corporation, College Station, Texas, USA) was used for data analysis. The inverse variance method was adopted to estimate the overall prevalence and 95.0% confidence intervals (CIs). The heterogeneity of the included studies was examined by Cochrane's Q statistic and I^2 statistic. Pooled prevalence and 95.0% CIs for PDF were calculated using a random effects model or a fixed effects model according to the heterogeneity of results. If no statistical heterogeneity was observed among the results ($p > 0.05$, $I^2 < 50.0\%$), the fixed effects model was used for meta-analysis. In contrast, if statistical heterogeneity was identified, the source of heterogeneity would be further analyzed, and a random effects model was used for meta-analysis. A meta-regression analysis was performed to assess the potential effect of important covariates that may lead to heterogeneity. Significant clinical heterogeneity was evaluated by subgroup analysis or a leave-one-out method by iteratively removing the included study. A sensitivity analysis was also performed to estimate the stability of the results. In addition, the proportions of patients diagnosed with the symptoms were retrieved from all included studies to assess the pooled prevalence of PDF. The odds ratios (ORs) and associated 95% CIs were used to assess the risk factors of PDF. Meanwhile, funnel plots, Begg's test, and Egger's test were used to detect publication bias.

Results

Search outcomes

A total of 3055 articles were identified from our search strategy. After removing 872 duplicates, 2100 articles were excluded, as the

titles and abstracts were not relevant to this study, and the full text of 83 articles was reviewed. Finally, 13 articles were included in the systematic review and meta-analysis.

Characteristics of the included studies

A total of 2118 participants were included in the 13 cross-sectional studies. Most articles (11/13) were published in the past 5 years, of which most (8/13) were conducted in China, with two in America, two in Italy, and one in Japan. The characteristics of the included studies are summarized in Table 1.

Risk of bias within studies

Thirteen studies were evaluated by AHRQ. There were eight high-quality studies with a score ranging between 8 and 9 points and five middle-quality studies with scores of 6–7 points. The details of the quality assessment are presented in Table 2.

Prevalence of PDF

In total, 13 of the included studies reported the prevalence of PDF. The prevalence of PDF ranged from 42.9% to 80.8%, irrespective of the PDF assessment method. The pooled prevalence of PDF was estimated to be 60.0% (95% CI: 53.0%, 66.0%, $I^2 = 89.3\%$, $p < 0.0001$).

Meta-regression analyses

The sample size, publication year, survey time, gender ratio, literature quality score, scale, country, and duration of dialysis were chosen as covariates. However, the regression coefficients of the above covariates showed no statistically significant difference between the intervention effect of each subgroup and the designated reference subgroup ($p > 0.05$; Table 3).

Subgroup analyses

Subgroup analyses were performed according to the PDF degree (mild, moderate, or severe) as determined by the scale score or DRT. The RPFS classification is based on the total score of each item added together: 0 = no fatigue, 1~3 = mild fatigue, 4~6 = moderate fatigue, and 7~10 = severe fatigue. The Chalder fatigue questionnaire classification is based on the interquartile range score: < 13 = no fatigue, 13~16 = mild fatigue, 17~22 = moderate fatigue, and ≥23 = severe fatigue. For DRT, PDF lasting >2 h after dialysis was defined as severe PDF, and <2 h was defined as mild PDF. The estimated pooled prevalence of mild, moderate, and severe PDF was 28.0%, 32.2%, and 20.2%, respectively. Sensitivity analysis was conducted due to the statistical heterogeneity of moderate and severe PDF ($I^2 = 84.1\%$, $I^2 = 92.8\%$). As for severe PDF, the study by Li et al. [16] might be a source of heterogeneity because the heterogeneity was reduced after excluding the study, with I^2 decreasing

Table 1 *Characteristics of the Included Studies.*

First author (year)	Country	Survey time	Sample size, No. (M/W)	Age (mean ± SD)	Duration of dialysis	Diagnostic criteria	Prevalence (%)	Risk factors
							PDF	
Wang 2021 [12]	China	2018.10–2019.10	280 (178/102)	46.8 ± 7.2	> 6 mo	CFQ	54.4	CRP, triacylglycerol, diastolic blood pressure after dialysis
Gordon 2011 [11]	America	NR	58 (38/20)	56.87 ± 14.54	≥3 mo	Questionnaire developed by Sklar	80.8	The average daily physical activity, dialysis vintage
Zhuang 2018 [14]	China	2016.12–2017.6	109 (75/34)	53.41 ± 10.25	≥3 mo	Self-designed questionnaire	71.7	NR
Mao 2021 [17]	China	2018.7–2020.7	120 (73/47)	52.75 ± 7.85	≥3 mo	RPFS	55.8	Sleep quality, ultrafiltration volume, serum calcium, mean arterial pressure after dialysis, higher interdialytic weight gain, recovery time
Zeng 2020 [13]	China	2018.12–2019.2	70 (45/25)	54.32 ± 11.61	≥3 mo	RPFS	78.6	Ultrafiltration volume, sleep quality, mean arterial pressure after dialysis
Li 2018 [18]	China	2017.5–2017.6	148 (84/64)	NR	≥3 mo	RPFS	54.7	Age, ultrafiltration volume, dialysis complications, hemoglobin, dialysis course
Lin 2019 [19]	China	2017.05–2018.04	65 (48/17)	49.20 ± 5.03	≥24 mo	FAI	43.1	Hemodialysis duration, ultrafiltration volume, dialysis complications
Bossola 2018 [5]	Italy	NR	271	NR	≥12 mo	SF-36 Vitality Subscale	60.5	Activity daily living
Sklar 1996 [3]	America	1995.06–1995.08	85 (50/35)	NR	≥3 mo	Self-designed questionnaire	50.6	NR
Kodama 2020 [10]	Japan	2016.06–2016.11	126 (85/41)	NR	≥3 mo	PDF scale	42.9	NR
Zu 2020 [20]	China	2018.03–2019.03	115 (59/56)	54.50 ± 12.76	≥6 mo	DRT	60.0	IDH, postdialysis Na, lactic acid, Charlson comorbidity index, ultrafiltration rate
Jiang 2022 [21]	China	2019.12	626 (385/241)	56.1 ± 12.9	≥3 mo	Self-designed questionnaire	55.5	HAMA score, HAMD score, ultrafiltration volume
Brys 2020 [22]	Italy	2017.01–2017.12	45 (29/16)	NR	≥12 mo	Questionnaire developed by Sklar	74.0	IL-10 levels before dialysis

Note. CFQ = Chalder Fatigue Questionnaire; CRP = C-reactive protein; FAI = Fatigue Assessment Instrument; HAMA = Hamilton Anxiety Scale; HAMD = Hamilton Depression Scale; IDH = intradialytic hypotension; IL = interleukin; M/W = men/women; NR = not reported; PDF = postdialysis fatigue; RPFS = Revised Piper Fatigue Scale; SD = standard deviation; Y = year.

Table 2 *AHRQ Critical Appraisal Checklist Applied for Included Studies in the Systematic Review.*

Author (year)	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_8	Q_9	Q_{10}	Q_{11}	Score	Quality of study
Wang (2021)	Y	Y	Y	Y	U	Y	Y	Y	N	Y	N	8	High
Gordon (2011)	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	N	9	High
Zhuang (2018)	Y	Y	Y	Y	U	N	N	Y	N	Y	N	6	Middle
Mao (2021)	Y	Y	Y	Y	U	Y	N	Y	N	Y	N	7	Middle
Zeng (2020)	Y	Y	Y	Y	U	Y	N	Y	N	Y	N	7	Middle
Li (2018)	Y	Y	Y	Y	U	Y	N	Y	Y	Y	N	8	High
Lin (2019)	Y	Y	Y	Y	U	Y	N	Y	N	Y	N	7	Middle
Bossola (2018)	Y	Y	Y	Y	U	Y	Y	Y	N	Y	N	8	High
Sklar (1996)	Y	Y	Y	Y	U	Y	Y	N	N	Y	Y	8	High
Kodama (2020)	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	N	9	High
Zu (2020)	Y	Y	Y	Y	U	Y	Y	Y	N	Y	N	8	High
Jiang (2022)	Y	Y	Y	Y	U	Y	N	Y	Y	Y	N	7	Middle
Brys (2020)	Y	Y	Y	Y	U	Y	N	Y	Y	Y	N	8	High

Note. Q_1 = Define the source of information (survey, record review); Q_2 = List inclusion and exclusion criteria for exposed and unexposed subjects (cases and controls) or refer to previous publications; Q_3 = Indicate period used for identifying patients.; Q_4 = Indicate whether or not subjects were consecutive if not population-based; Q_5 = Indicate if evaluators of subjective components of study were masked to other aspects of the status of the participants; Q_6 = Describe any assessments undertaken for quality assurance purposes (e.g., test/retest of primary outcome measurements); Q_7 = Explain any patient exclusions from analysis; Q_8 = Describe how confounding was assessed and/or controlled; Q_9 = If applicable, explain how missing data were handled in the analysis; Q_{10} = Summarize patient response rates and completeness of data collection; Q_{11} = Clarify what follow-up, if any, was expected and the percentage of patients for which incomplete data or follow-up was obtained.
N = No; U = Unclear; Y = Yes.

Table 3 *Meta-Regression Analyses Results.*

Covariate	β	95% CI	*p*
Sample size	−0.000	−0.001 to 0.000	0.363
Publication year	−0.025	−0.248 to 0.198	0.863
Survey time	−0.020	−0.052 to 0.012	0.193
Men to women ratio	−0.000	−0.001 to 0.000	0.808
Score	−0.018	−0.160 to 0.197	0.824
Scale	−0.014	−0.048 to 0.021	0.397
Country			
America	0.025	0.751 to 1.400	0.861
China	0.918	0.718 to 1.173	0.449
Italy	0.791	0.542 to 1.154	0.194
Duration of dialysis	0.026	−0.070 to 0.768	0.560

Note. CI = confidence interval.

Table 4 *Subgroup Analyses of the PDF.*

Subgroup	Number of studies	Results of heterogeneity		Effect model	Prevalence (%, 95% CI)
		(I^2, %)	*p*		
PDF degree					
Mild	4	0	0.526	Fixed	28.0 (23.9–32.1)
Moderate	3	84.1	<0.001	Random	32.2 (19.8–44.5)
Severe	4	92.8	<0.001	Random	20.2 (7.4–33.1)
Scales for PDF					
RPFS	3	87.8	<0.001	Random	60.3 (55.1–65.4)
Questionnaire developed by Sklar	3	92.1	<0.001	Random	70.1 (48.1–92.2)
Other PDF scale	6	86.7	<0.001	Random	53.1 (45.6–60.6)
Survey time					
The years before 2016	2	86.1	<0.001	Random	59.1 (52.2–66.1)
The years after 2016	9	18.3	0.269	Fixed	45.9 (39.2–52.6)
Region					
Asia	9	86.5	<0.001	Random	56.1 (49.2–62.9)
Non-Asia	4	90.8	<0.001	Random	67.6 (52.6–82.6)

Note. CI = confidence interval; PDF = postdialysis fatigue.

from 92.8% to 76.9%. The disparity in dialysis frequency may be attributed to the heterogeneity of severe PD.

The estimates of pooled prevalence of RPFS, based on the questionnaire developed by Sklar and other PDF scales, were 60.3%, 70.1%, and 53.1%, respectively. Due to the high statistical heterogeneity (I^2 = 87.8%, I^2 = 92.1%, I^2 = 86.7%), sensitivity analysis was adopted. Heterogeneity in the scale of RPFS was significantly reduced from 87.8% to 0.0% when Zeng's study [11] was eliminated, possibly because patients with severe trauma within 1 month were excluded in Zeng's study, resulting in a lower total score on the behavioral/severity dimension of the scale. As for the questionnaire developed by Sklar [3], the heterogeneity was decreased from 92.1% to 61.4% after excluding the study by Sklar et al [10]. The heterogeneity may result from different dialysis methods (conventional dialysis with hollow fiber dialyzers vs. central venous catheterization).

Subgroup analyses were conducted based on the survey time before and after 2016, as fatigue was identified as a core prognostic outcome in 2016. The estimated pooled prevalence of PDF was 59.1% before 2016 and 45.9% after 2016, with a statistical heterogeneity of 86.1% and 18.3%, respectively. Subgroup analyses of the PDF are displayed in Table 4.

Risk factors

In total, 26 potential risk factors related to PDF were identified, including C-reactive protein, triacylglycerol, diastolic blood pressure after dialysis, the average daily physical activity, dialysis vintage, sleep quality, ultrafiltration volume, serum calcium, mean arterial pressure after dialysis, higher interdialytic weight gain, DRT, sleep quality, age, dialysis complications, hemoglobin, dialysis course, hemodialysis duration, activity daily living, intradialytic hypotension, postdialysis Na, lactic acid, Charlson comorbidity index, ultrafiltration rate, Hamilton Anxiety Scale score, Hamilton depression scale score, and interleukin-10 levels before dialysis. However, among them, only ultrafiltration volume, sleep quality, and mean arterial pressure after dialysis have sufficient data and could be synthesized. In the analysis of sleep quality and mean arterial pressure after dialysis, a fixed effects model was used, as no statistically significant heterogeneity was observed. While the statistical heterogeneity of ultrafiltration volume was observed, thus a random effects model was used. Sensitivity analysis was performed to explore the source of heterogeneity. After excluding the study by Lin et al,[19] the heterogeneity was reduced from 99.0% to 72.0%, which may be attributed to the inclusion of patients with MHD with coronary heart disease (Table 5).

Sensitivity analysis/publication bias

Sensitivity analysis suggested that the meta-analysis results were relatively stable. Funnel plots and Egger's test were used to

Table 5 *Pooled Risk Factors of PDF.*

Risk factors	Number of included studies	Results of heterogeneity		Effect model	Results of meta-analysis	
		p	I^2 (%)		OR (95% CI)	*p*
Ultrafiltration volume	5	<0.001	99.0	Random	2.93 (0.83–10.40)	= 0.10
Sleep quality	2	= 0.99	0.0	Fixed	0.24 (0.19–0.30)	<0.001
Mean arterial pressure after dialysis	2	= 0.55	0.0	Fixed	0.96 (0.93–1.00)	= 0.03

Note. CI = confidence interval; OR = odds ratio; PDF = postdialysis fatigue.

evaluate publication bias. The funnel plot showed no publication bias, whereas the results of Begg's test ($Z = 0.583$) and Egger's test ($p = 0.378$) indicated a low risk of publication bias in this analysis.

Discussion

This study included 13 studies with 2,118 patients. Regarding the quality of the included studies, the AHRQ scores ranged from 5 to 6, indicating a moderate or higher level of quality. Meta-regression analyses showed no statistically significant difference among the covariates of sample size, publication year, survey time, gender ratio, the literature quality score, scale, country, and duration of dialysis. However, the heterogeneity was significantly reduced in the subgroup analysis by PDF degree, scales for PDF assessment, and survey time, suggesting that the above factors may introduce heterogeneity. The pooled prevalence of PDF was 60.0%, which is lower than the systematic review published in 2018 [23]. This discrepancy might be attributed to our strict inclusion and exclusion criteria, whereas the other's subjects included a wider range of chronic fatigue participants. Furthermore, PDF is largely ignored in the clinical setting, and there are few effective therapies for PDF. The symptom has not been explored in other regions than China, Japan, America, and Italy. Future research should be conducted in countries that lack data on the prevalence of PDF.

This study demonstrated a difference between the pooled prevalence of PDF and the degree of fatigue. Moderate PDF was more prevalent than mild or severe PDF, which is consistent with other research results [24]. This finding may be related to the following two factors. On the one hand, the lack of recognition of PDF may result in overlooking PDF. Mild PDF could be ignored, whereas severe PDF could be mistaken for chronic fatigue by health care workers. On the other hand, some of the fatigue scales are not specific for PDF, and the limited sensitivity reduces the detection of mild PDF. Therefore, health care workers should pay more attention to PDF and their treatment. Future studies should lead to the development of different therapies for PDF.

Among the included studies, nine different scales were used to measure PDF, and the distinct instruments may limit the internal validity of this study [25]. Among the nine scales, only the PDF scale was designed for PDF in hemodialysis patients, showing good reliability and validity [10]. However, the new assessment scale was first applied in 2020 and needs further verification. RPFS was the most frequently used tool, but it was designed for cancer-related fatigue, yielding a lower prevalence of PDF (60.3%). The first used tool was the questionnaire developed by Sklar. The fatigue index considers the duration, frequency, and intensity of PDF, but its sensitivity and specificity have not been evaluated [3]. Fatigue Assessment Instrument has high internal consistency and good concurrent and discriminant validity and can distinguish the fatigue of healthy people from the fatigue from hemodialysis and different diseases [26]. Currently, there is no international consensus to measure PDF, so a multidisciplinary collaboration is recommended. Health care workers and researchers should work together to agree on the use of a dedicated scale to assess PDF to improve clinical treatment.

The prevalence of PDF has varied over time. In November 2016, the standardized outcomes in nephrology-hemodialysis Fatigue Consensus Workshop identified fatigue as a core prognostic outcome [27]. Although the number of studies on chronic fatigue has increased year by year, few studies focused on PDF. Patients suffering from PDF received prompt treatment although the symptom was mistaken for chronic fatigue. In the last 5 years, a growing number of studies have investigated PDF, increasing its awareness among health care workers. Furthermore, the symptom of PDF in some patients is prevented before occurring, which may explain the higher prevalence of PDF after 2016 compared with before 2016. ERSD is a global public health problem, and this study suggests a higher estimated pooled prevalence of PDF in non-Asian countries than in Asia. This difference in prevalence may be attributed to the particularly high prevalence of kidney disease in Asia. With the increased awareness of the symptom of PDF among health care staff, effective measures were taken as soon as possible. An international survey indicated that 68.0% of patients reported taking longer than 2 hours to recover from a dialysis session, with 27.0% taking more than 6 hours [28]. Therefore, it is important to improve the awareness and knowledge of PDF in non-Asian countries.

Sleep quality was significantly associated with PDF. Among MHD patients, the majority (68.1%) were poor sleepers [29], which might be because MHD patients generally need lifelong treatment, and the relatively high treatment cost brings a considerable economic burden to the patients and their families. Therefore, MHD patients are likely to experience negative emotions, resulting in sleep disorders and poor sleep quality. Thus, health care workers should provide patients with a quiet and comfortable treatment environment during dialysis, fully assess the patient's psychological state, and carry out a personalized psychological intervention.

This study identified the mean arterial pressure after dialysis as a risk factor for PDF. Previous studies reported that low blood pressure was significantly associated with longer recovery time [30]. Lower mean arterial pressure after dialysis leads to hypoperfusion of vital organs and affects the recovery time of the brain and heart, prolonging the recovery time of fatigue after dialysis. In addition, cold dialysis was found to relieve the symptom of fatigue [31], as it possibly improves hemodynamic stability and systolic blood pressure [32]. Therefore, monitoring the blood pressure of patients during dialysis and actively preventing and treating severe hypotension may alleviate fatigue after dialysis.

Some studies have demonstrated the relationship between ultrafiltration volume and PDF. First, ultrafiltration volume overload is usually caused by an excessive increase in body weight during dialysis, which increases extracellular water, impairing cardiac and respiratory function, and providing a physiological basis for PDF [33]. Moreover, excessive ultrafiltration increases the changes in plasma and intracellular fluid movement during dialysis and increases the risk of dialysis-related hypotension [34]. Therefore, the water intake should be appropriately reduced during dialysis treatment to effectively reduce the impact of PDF on life.

To our knowledge, this study was the first systematic review and meta-analysis to analyze the pooled prevalence and risk factors of PDF. This study may enhance health care workers' understanding of PDF, promoting its prevention, assessment, diagnosis, treatment, and monitoring. Overall, one of this study's strengths is the thorough literature search across nine electronic databases to limit the risk of missing research. Moreover, the quality of included studies

was high or moderate. Meta-regression, subgroup analyses, and sensitivity analyses were performed to explore the possible reasons for heterogeneity. However, the limitations of this study should also be acknowledged. First, the included studies adopted different scales for PDF, which affected the internal validity of this study. Second, the risk factors available from each study were inconsistent, so some risk factors for PDF could not be analyzed in depth. Meanwhile, the association between PDF and cardiovascular events, stroke, and mortality, and the potential possible effect of racial disparities could not be explored due to the limited number of studies. Our team aims to carry out relevant original studies in the future. Third, the included studies were conducted mainly in China, possibly raising bias. Finally, relatively high heterogeneity was observed, and the results require cautious interpretation.

Clinical implications

This study has demonstrated the prevalence of PDF and its related factors. Exploring the prevalence and risk factors of PDF can provide an up-to-date theoretical basis for the management of maintenance hemodialysis patients. Most significantly, this study emphasizes the importance of PDF.

Conclusion

We found a pooled prevalence of PDF of 60.0%. With such a high prevalence, health care workers should pay more attention to PDF. Ultrafiltration volume, sleep quality, and mean arterial pressure after dialysis are related to PDF. These findings suggest that future research with a large overall sample should be conducted to determine which risk factors most strongly affect the symptom of PDF, its underlying mechanism, and the most effective treatments.

Conflict of interest

None.

Ethics approval statement

This is not a clinical trial; this study did not require the approval of an Ethics Committee because it is based entirely on previously published studies.

Patient consent statement

As it is based entirely on previously published studies, this study did not require the approval of patients. In addition, we have asked the authors of including studies for permission to cite data.

Clinical trial registration

As it is based entirely on previously published studies, this study protocol has registered on the PROSPERO website (CRD42022309395).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.anr.2022.11.002.

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