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REVIEW

Predictors of Readmission, for Patients with Chronic Obstructive Pulmonary Disease (COPD) – A Systematic Review

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Introduction: Chronic obstructive pulmonary disease (COPD) is the third-leading cause of death globally and is responsible for over 3 million deaths annually. One of the factors contributing to the significant healthcare burden for these patients is readmission. The aim of this review is to describe significant predictors and prediction scores for all-cause and COPD-related readmission among patients with COPD.

Methods: A search was conducted in Ovid MEDLINE, Ovid Embase, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials, from database inception to June 7, 2022. Studies were included if they reported on patients at least 40 years old with COPD, readmission data within 1 year, and predictors of readmission. Study quality was assessed. Significant predictors of readmission and the degree of significance, as noted by the *p*-value, were extracted for each study. This review was registered on PROSPERO (CRD42022337035).

Results: In total, 242 articles reporting on 16,471,096 patients were included. There was a low risk of bias across the literature. Of these, 153 studies were observational, reporting on predictors; 57 studies were observational studies reporting on interventions; and 32 were randomized controlled trials of interventions. Sixty-four significant predictors for all-cause readmission and 23 for COPD-related readmission were reported across the literature. Significant predictors included 1) pre-admission patient characteristics, such as male sex, prior hospitalization, poor performance status, number and type of comorbidities, and use of long-term oxygen; 2) hospitalization details, such as length of stay, use of corticosteroids, and use of ventilatory support; 3) results of investigations, including anemia, lower FEV_1, and higher eosinophil count; and 4) discharge characteristics, including use of home oxygen and discharge to long-term care or a skilled nursing facility.

Conclusion: The findings from this review may enable better predictive modeling and can be used by clinicians to better inform their clinical gestalt of readmission risk.

Keywords: predictors, readmission, chronic obstructive pulmonary disease

Introduction

Chronic obstructive pulmonary disease (COPD) is a common respiratory condition characterized by persistent airflow limitation[1] and is thought to affect over 10% of the population.[2] As a consequence of its chronicity, COPD is responsible for over 3 million deaths globally, making it the third most common cause of death.[3]

Patients with COPD commonly require hospitalized care, and COPD is one of the most common causes of hospitalization, among chronic diseases.[4] Moreover, a notable proportion of patients with COPD will be readmitted, making readmission one of the factors contributing to the significant healthcare burden for these patients. It has been estimated that up to 50% of patients diagnosed with COPD are readmitted within 30 days of initial discharge in the USA.[5] In addition to the utilization of healthcare resources, readmission is associated with a worse overall prognosis.[6] Over the past decade, there has been an increased interest in identifying predictors and predictive models for readmission.[7] Several systematic reviews have attempted

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to summarize the literature, but they only focused on all-cause or COPD-related readmission alone, and/or did not undertake a quality assessment of the included studies.[8–10] In addition, given the rapidly developing literature, with many studies being reported in the past few years, these systematic reviews may not account for current findings.

The aim of this systematic review is to describe significant predictors and prediction scores for all-cause and COPD-related readmission among patients with COPD.

Methods

This review was registered a priori on PROSPERO (CRD42022337035) and reported as per the PRISMA statement.

Search Strategy

A comprehensive search strategy was developed for Ovid MEDLINE, Ovid Embase, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials from database inception to June 7, 2022, using a combination of database-specific subject headings and text words for the main concepts of COPD and hospital readmissions. An expanded search filter for clinical prediction guides was used. Results were limited to adult human studies. No other limits were applied (Appendix 1).

Eligibility Criteria

Two review authors (RC, OWS) independently screened articles for their eligibility for inclusion. A calibration exercise of 20 articles was undertaken to ensure concordance between reviewers. Discrepancies were resolved by discussion and consensus. If consensus could not be achieved, a third review author (RW) participated in the discussion to resolve discrepancies.

Articles were eligible after level 1 title and abstract screening, if they reported on primary research articles reporting on patients with COPD and readmission. Secondary research articles, such as review articles and economic analyses, as well as editorials/commentaries, were excluded at this stage. Studies included after level 2 full-text screening eligibility criteria required studies to report on patients at least 40 years old with COPD, readmission data within 1 year of a COPD hospitalization, and predictors of readmission. Studies including patients admitted for reasons unrelated to acute exacerbations of COPD (eg pneumonia, acute hypercapnic respiratory failure, obstructive sleep apnea, lung cancer, anxiety/depression) and studies reporting on home care/telemonitoring were excluded at this stage, to limit included articles to only patients with COPD.

Data Extraction

Two of the three review authors (RC, OWS, JHBI) conducted data extraction. As with screening, discrepancies were resolved by discussion and consensus, with or without the input of a third reviewer (RW). Study characteristics of country, sample size, age of participants, and percentage of females enrolled in study were noted. Studies were classified as either assessing predictors or assessing interventions. Studies assessing interventions were further subclassified as either observational cohort studies or randomized controlled trials. Significant predictors of readmission and the degree of significance, as noted by the *p*-value, were extracted for each study. For studies that did not report *p*-values, *p*-values were calculated based on the provided statistics (eg odds ratio and 95% confidence intervals) where possible.

Study Quality

Study quality was assessed for each study. For randomized controlled trials, the risk of bias version 2 tool was used.[11] For observational studies reporting on interventions, the ROBINS-I tool was used.[12] For observational studies reporting on predictors, the ROBINS-E tool was used.[13]

Synthesis

Significant predictors were reported by the time of readmission post-discharge and the degree of significance. Predictors were reported as significant predictors for the timepoint of 1-month readmission, the interval of 2–3-month readmission, and the interval of 6–12-month readmission. Predictors were further reported based on whether they were significant at a type I error of 0.05, type I error of 0.01, or no degree of significance available. Significant predictors, as reported by the authors (Supplementary Tables 1 and 2), were grouped together into similarly reported predictors across the literature (eg all mentions of hospital length of stay were grouped together).

Because of the non-uniform reporting of non-significant predictors, where some studies explicitly reported non-significant predictors in the methods/results and others only mentioned significant predictors, non-significant predictors were not presented.

Results

In total, 4035 articles were identified from the database search. After 970 duplicates were removed, 3065 records were screened. Ultimately, 242 articles[14–255] reporting on 16,471,096 patients were included in this review (Figure 1). Across the literature, there was generally a low risk of bias (Figure 2).

Overall, 153 studies were observational studies reporting on predictors; 57 studies were observational studies reporting on interventions; and 32 were randomized controlled trials of interventions. The studies were published between 1997 and 2022, with over half of the studies published since 2017. Over one-third of articles (91 studies, 37.6%) originated from the USA; 31 (12.8%) studies originated from Spain, 14 (5.8%) from Canada, 13 (5.4%) from the UK, and 13 (5.4%) from China. Sample sizes ranged from 8 to 4,587,542. The mean/median age was greater than 60

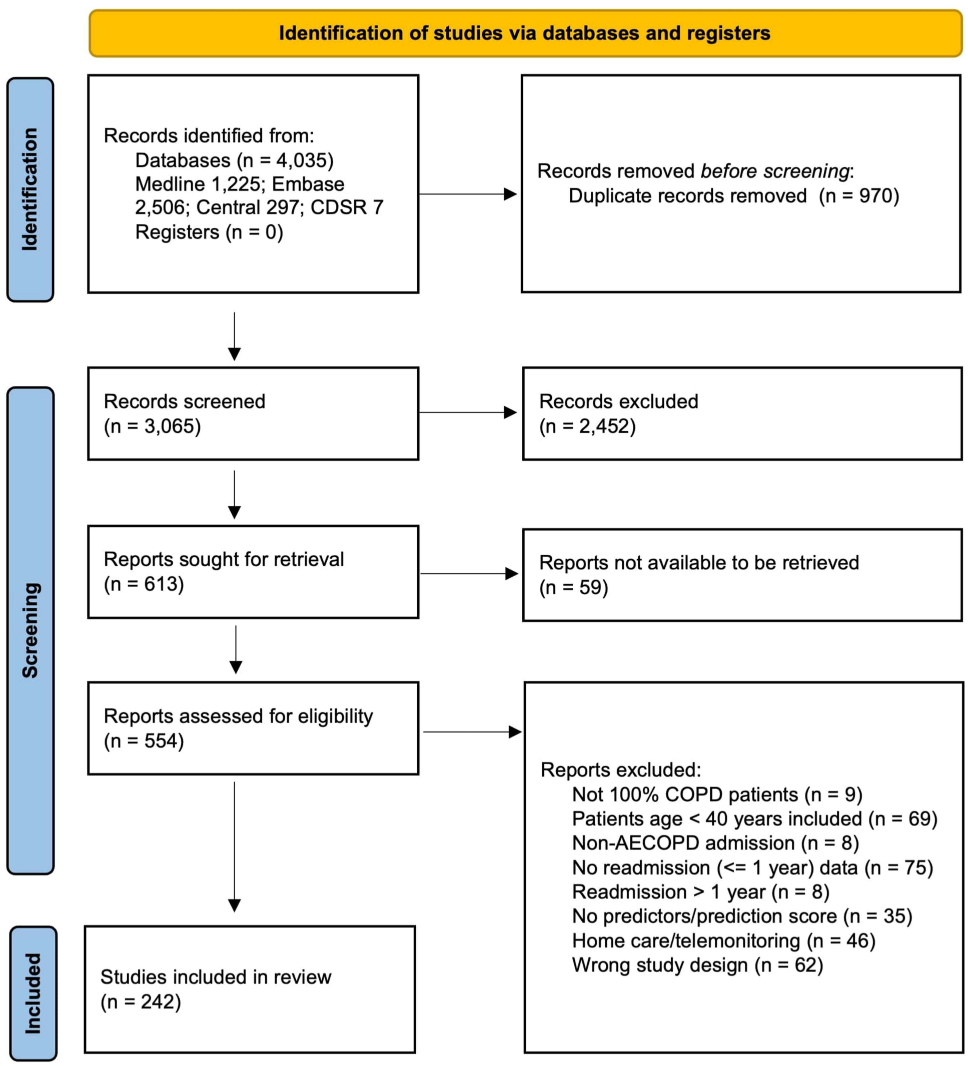

Figure 1 PRISMA flow diagram.

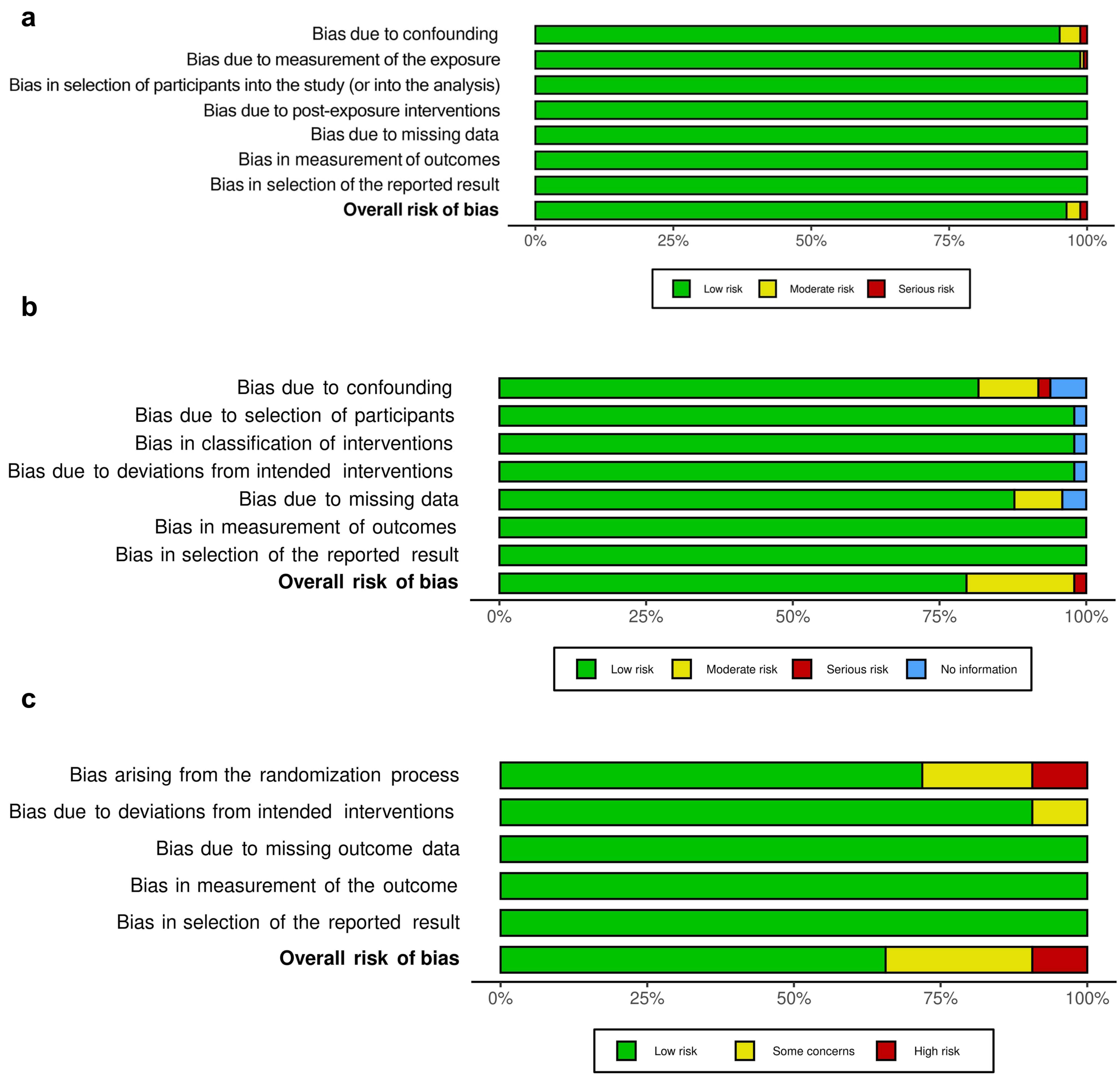

Figure 2 Quality assessment: (**a**) studies assessing predictors (ROBINS-E); (**b**) cohort studies assessing interventions (ROBINS-I); (**c**) randomized controlled trials assessing interventions (RoB 2).

years for nearly all studies. The percentage of females in a study ranged from 0.0% to 80.0%. Individual study characteristics are reported in Table 1 and Table 2.

A total of 64 significant predictors for all-cause readmission were reported across the literature. Summarizing across all readmission time frames, male sex, prior hospitalization, poorer performance status/activities of daily living, and older age were the most frequently reported patient characteristics that were predictors of readmission. Other significant predictors were COPD severity, alcohol/drug abuse, malnutrition, and history of community-acquired pneumonia (Figure 3a). Heart failure, mental health comorbidity, higher Charlson comorbidity index, diabetes, higher number of comorbidities, chronic kidney disease, and cancer were among the most commonly reported comorbidity predictors of readmission (Figure 3b). Among medications used prior to admission that were significant of readmission, long-term oxygen therapy was the most commonly reported predictor (Figure 3c). Hospital length of stay, non-invasive ventilation, intubation, and admission to the intensive care unit were the most common hospital care predictors of readmission

Table 1 Studies Assessing Predictors

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Abrams 2011[14]	USA	28,156	69.1±10.6	[redacted]	3.1%
Abusaada 2017[15]	USA	1419	65.1±2.3	[redacted]	47.7%
Agarwal 2016[18]	USA	7257	[redacted]	75–84	64.2%
Aksoy 2018[19]	Turkey	2727	69.8±10.2	[redacted]	31.5%
Al Aqqad 2017[20]	Malaysia	81	[redacted]	72.0 (66.4–78.0)	2.5%
Almagro 2006[21]	Spain	129	72.0±9.2	[redacted]	7.0%
Almagro 2012[22]	Spain	606	72.6±9.9	[redacted]	2.0%
Almagro 2014[23]	Spain	983	72.3±9.7	[redacted]	8.5%
Alpaydin 2021[24]	Turkey	300	73.1±10.1	[redacted]	28.3%
Alqahtani 2021[25]	UK	82	71.0±10.4	[redacted]	51.2%
Bade 2019[29]	USA	48,888	68.7±10.1	[redacted]	3.7%
Bahadori 2009[30]	Canada	310	74.0±12.0	[redacted]	46.5%
Baker 2013[31]	USA	6095	[redacted]	55–59	58.9%
Barba 2012[33]	Spain	275,512	72.0±15.4	[redacted]	30.0%
Bartels 2018[34]	Canada	511	66.5±13.3	[redacted]	35.2%
Belanger 2018[36]	Canada	479	68.9±9.4	[redacted]	48.0%
Bernabeu-Mora 2017[38]	Spain	103	71.0±9.1	[redacted]	6.8%
Bishwakarma 2017[40]	USA	6066	76.9±7.2	[redacted]	67.3%
Boeck 2014[41]	Switzerland	43	Not reported	[redacted]	53.5%
Boixeda 2017[42]	Spain	120	72.9±8.6	[redacted]	2.5%
Bollu 2013[43]	USA	2463	68.6±10.6	[redacted]	57.2%
Bollu 2017[44]	USA	13,675	67.1±12.4	[redacted]	55.6%
Breyer-Kohansal 2019[45]	Austria	823	68.5±10.2	[redacted]	40.9%
Brownridge 2017[46]	Australia	130	72.9±10.7	[redacted]	51.6%
Buhr 2019[49]	USA	1,622,983	68.0±11.9	[redacted]	58.9%
Buhr 2020[48]	USA	1,622,983	68.0±11.9	[redacted]	57.8%
Candrilli 2015[50]	USA	264,526	67.6±11.2	[redacted]	50.9%
Carneiro 2010[51]	Portugal	45	68±12.4	[redacted]	15.6%
Chan 2011[52]	Hong Kong	65,497	76.8±9.6	[redacted]	23.0%
Chang 2014[53]	China	135	[redacted]	66 (60–74)	11.9%
Chawla 2014[54]	USA	54	70.0±12.0	[redacted]	70.0%
Chen 2006[57]	Taiwan	145	72.2±10.0	[redacted]	26.9%

(*Continued*)

Table 1 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Chen 2009[56]	Canada	108,726	72.3±10.9	[redacted]	45.5%
Chen 2021[55]	China	636	70.8±9.9	[redacted]	33.2%
Chu 2004[58]	Hong Kong	110	73.7±7.6	[redacted]	22.7%
Chung 2010[59]	Australia	100	70.6±9.5	[redacted]	44.0%
Coban Agca 2017[60]	Turkey	1490	67.7±11.1	[redacted]	35.0%
Connolly 2006[62]	New Zealand	7113	[redacted]	65–74	47.7%
Couillard 2017[65]	Canada	167	71.4±10.3	[redacted]	48.5%
Coventry 2011[66]	UK	79	65.3±9.9	[redacted]	44.3%
Crisafulli 2014[68]	Spain	123	69.4±9.8	[redacted]	6.6%
Crisafulli 2015[70]	Spain	125	69.2±9.8	[redacted]	6.4%
Crisafulli 2016[69]	Spain	110	70.5±9.6	[redacted]	6.4%
de Miguel-Diez 2016[74]	Spain	301,794	74.8±10.0	[redacted]	14.0%
Duman 2015[76]	Turkey	1704	Not reported	[redacted]	34.5%
Ehsani 2019[79]	USA	42	70.4±8.1	[redacted]	33.3%
Emtner 2007[80]	Sweden	21	65.0±9.3	[redacted]	66.7%
Eriksen 2010[81]	Denmark	300	72.1	[redacted]	61.7%
Ernst 2019[82]	Canada	203,642	Not reported	[redacted]	Not reported
Euceda 2018[83]	USA	272	73.2±12.4	[redacted]	56.3%
Fernandez-Garcia 2020[84]	Spain	253	68.99.8	[redacted]	22.5%
Fu 2015[85]	USA	15,755	71.0±12.5	[redacted]	52.9%
Ganapathy 2017[86]	USA	11,496	70.7±10.8	[redacted]	52.5%
Garcia-Aymerich 2003[87]	Spain	340	69±9	[redacted]	Not reported
Garcia-Pachon 2021[89]	Spain	106	73±10	[redacted]	21.7%
Garcia-Sanz 2020[90]	Spain	602	73.8±10.6	[redacted]	14.0%
Gavish 2015[91]	Israel	195	66±10	[redacted]	17.4%
Ghanei 2007[97]	Iran	98	58.3±11.0	[redacted]	37.0%
Giron 2009[98]	Spain	78	71±10	[redacted]	0.0%
Glaser 2015[99]	USA	617	Not reported	[redacted]	Not reported
Gonzalez 2008[100]	Spain	112	69.3±7.5	[redacted]	Not reported
Goto 2017[102]	USA	845,465	70	[redacted]	59.0%
Goto 2018[101]	USA	76,697	[redacted]	76 (71–83)	59.6%
Goto 2020[103]	USA	905	[redacted]	76 (68–82)	54.0%

(*Continued*)

Table 1 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Gudmundsson 2005[104]	Sweden	406	69.2±10.5	[redacted]	51.2%
Guerrero 2016[105]	Spain	378	71.4±10.0	[redacted]	15.9%
Hajizadeh 2015[108]	USA	4791	74.3±6.4	[redacted]	Not reported
Hakansson 2020[109]	Denmark	4022	[redacted]	73.1 (63.7–81.1)	55.2%
Harries 2017[110]	UK	19,551	72.4±10.8	[redacted]	47.8%
Hartl 2016[111]	European countries	16,016	70.8±10.8	[redacted]	32.2%
Hasegawa 2016[112]	USA	3084	[redacted]	70 (61–79)	50.0%
Hegewald 2020[114]	USA	2445	68.4±11.6	[redacted]	50.7%
Hemenway 2017[115]	USA	369	66	[redacted]	57.5%
Huertas 2017[116]	Spain	150	[redacted]	70 (65–76)	3.0%
Ingadottir 2018[117]	Iceland	121	73.7±9.0	[redacted]	57.0%
Islam 2015[120]	USA	350	Not reported	[redacted]	54.9%
Iyer 2016[121]	USA	422	64.8±11.7	[redacted]	49.9%
Jacobs 2018[122]	USA	1,055,830	[redacted]	68 (59–77)	58.5%
Janson 2020[123]	Sweden	51,247	74.6±10.1	[redacted]	54.8%
Jing 2016[127]	China	8	Not reported	[redacted]	Not reported
Jo 2020[128]	South Korea	15,101	73.4±9.7	[redacted]	25.4%
Johannesdottir 2013[129]	Denmark	3176	[redacted]	72.1 (65.2–77.7)	55.2%
Jones 2020[130]	UK	1029	74.4±9.9	[redacted]	49.0%
Kasirye 2013[132]	USA	209	Not reported	[redacted]	Not reported
Kerkhof 2020[135]	UK	16,661	75.1±9.9	[redacted]	50.3%
Keshishian 2019[136]	USA	7892	78.1±7.6	[redacted]	57.7%
Kim 2010[139]	South Korea	77	69.2±9.4	[redacted]	16.9%
Kim 2021[140]	South Korea	4867	[redacted]	75–79	30.9%
Kishor 2020[143]	India	100	64.0±8.5	[redacted]	16.0%
Ko 2020[144]	Hong Kong	346	74.9±7.8	[redacted]	3.8%
Lau 2017[151]	USA	597,502	Not reported	[redacted]	55.3%
Law 2016[152]	Australia	90	70.7±9.3	[redacted]	50.0%
Li 2020[156]	China	108	70.6±9.3	[redacted]	21.3%
Lindenauer 2014[158]	USA	25,628	[redacted]	69 (61–77)	56.6%
Lindenauer 2018[157]	USA	2340	76.3±7.5	[redacted]	56.1%
Liu 2007[159]	Taiwan	100	73.8±10.6	[redacted]	15.0%

(*Continued*)

Table 1 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Loh 2017[160]	USA	123	64.9±11.3		47.2%
Marcos 2017[161]	USA	143	72.3±10.0		7.0%
Martinez-Gestoso 2021[162]	Spain	615	73.9±10.6		13.8%
Myers 2021[168]	USA	7825	Not reported		55.1%
Myers 2021[167]	USA	333,429		70 (61–80)	57.1%
Nantsupawat 2012[170]	USA	81	73.9		53.1%
Narewski 2015[171]	USA	160	63.9±10.8		58.8%
Nastars 2019[172]	USA	298,706	77.7±7.7		59.6%
Ng 2007[173]	China	376	72.2±8.4		14.9%
Nguyen 2015[176]	USA	2910	72±11		57.1%
Niu 2021[177]	China	378	75.2±8.9		15.9%
Njoku 2022[178]	Australia	2448		72 (64–80)	50.1%
Osman 1997[180]	UK	266	68.0±9.1		47.0%
Ozyilmaz 2013[182]	Turkey	107	66.3±8.6		15.0%
Park 2016[185]	South Korea	339,379	71.5±11.6		29.8%
Peng 2021[187]	China	123	71.1±9.6		26.8%
Pienaar 2015[189]	South Africa	178	63±12		42.1%
Ponce Gonzalez 2017[191]	Spain	361	75.0±11.5		21.1%
Portoles-Callejon 2020[192]	Spain	108	71.5±11.7		18.5%
Pouw 2000[194]	Netherlands	28	70.0±7.2		42.9%
Pozo-Rodriguez 2015[195]	Spain	5174	Not reported		Not reported
Price 2006[196]	UK	7529	Not reported		Not reported
Quintana 2022[198]	Spain	876	73.7±9.4		20.5%
Rahimi-Rad 2015[199]	Iran	100	70.8±10.3		31.0%
Rinne 2015[203]	USA	25,301	68.9±10.5		3.2%
Rinne 2017[202]	USA	33,558	68.7±10.4		3.4%
Rinne 2017[201]	USA	33,558	68.7±10.4		3.4%
Roberts 2002[204]	UK	1373		72 (66–78)	Not reported
Roberts 2011[205]	UK	9716		65–74	50.0%
Roberts 2015[208]	USA	306	70.3±12.3		56.2%
Roberts 2016[206]	USA	3612	66.6±12.1		67.2%
Roberts 2020[207]	USA	10,405	72.6±10.3		62.3%

(*Continued*)

Table 1 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Rodrigo-Troyano 2018[209]	Spain	106	71±8		17.9%
Ruby 2020[210]	Egypt	190	63.1±10.1		0.0%
Shah 2015[214]	USA	947,084	Not reported		Not reported
Shani 2022[215]	Israel	1203	70.6±11.0		37.3%
Sharif 2014[216]	USA	8263	56.5±5.7		58.8%
Shay 2020[218]	USA	111	67.1±11.7		62.2%
Simmering 2016[221]	USA	286,313	Not reported		Not reported
Singer 2020[223]	USA	28,240	72.7±8.7		51.9%
Singh 2016[224]	USA	135,498		75–84	60.2%
Snider 2015[225]	USA	378,419	76.2±6.9		56.8%
Stefan 2017[228]	USA	13,893		69	57.6%
Stuart 2010[232]	USA	6322	74.7±0.4		48.9%
Tran 2016[234]	USA	375	59.3±7.4		64.0%
Turner 2014[235]	England	1942	Not reported		Not reported
Ushida 2022[236]	Japan	3396	75.0±11.2		20.4%
Wang 2013[242]	Norway	481	72.8±10.5		53.4%
Wong 2008[244]	Canada	109	63.0±14.5		38.5%
Wu 2020[245]	Taiwan	625	76.3±10.6		12.0%
Wu 2021[247]	Taiwan	625	76.3±10.6		12.0%
Wu 2021[246]	USA	91	60±11		63.7%
Yilmaz 2021[249]	Turkey	110	67.8±9.3		18.2%
Yu 2015[250]	USA	18,282	56.6±5.8		62.4%
Zapatero 2013[253]	Spain	313,233	72.7±15.7		30.3%
Zhou 2021[254]	China	417	75±12		20.4%
Zhu 2021[255]	China	239		72	16.7%

Note: Blacked out cells indicate that data are not available/applicable.

(Figure 3d). Among laboratory values, lower FEV_1 and anemia were the most common predictors (Figure 3e). Use of systemic corticosteroids during hospital admission was the most frequently reported predictor of readmission, among medications used during admission (Figure 3f). Discharge to long-term care or a skilled nursing facility was the most commonly reported predictor of readmission, of assessed predictors after admission (Figure 3f–h). Degrees of significance, and the specific studies reporting on each significant predictor, are reported in Table 3.

For COPD-related readmission, 23 significant predictors were found. The most common patient characteristics that were predictors were older age and prior hospitalization (Figure 4a). Mental health comorbidity, diabetes, high Charlson/Elixhauser comorbidity index, and cancer were the most frequently reported comorbidity predictors of readmission

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Table 2 Studies Assessing Interventions

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Cohort Studies					
Adamson 2016[16]	Canada	462	70.6±13.2		40.9%
Agarwal 2018[17]	USA	1248	Not reported		Not reported
Alshehri 2021[26]	Saudi Arabia	80	67.0±10.3		41.3%
Ankjaergaard 2017[27]	Denmark	201	71.5±10.8		56.7%
Ban 2012[32]	Malaysia	193	68.5±8.8		13.0%
Bashir 2016[35]	USA	461	71.7±13.3		32.5%
Bhatt 2017[39]	USA	187	70.4±11.2		61.0%
Collinsworth 2018[61]	USA	308	70.5±12.2		58.4%
Cope 2015[64]	UK	464	Not reported		Not reported
Dalal 2012[71]	USA	1936	63.9±9.9		55.4%
De Batlle 2012[72]	Spain	274	68±8		6.9%
Gay 2020[92]	USA	157	70.6±11.2		56.1%
Gentene 2021[93]	USA	Not reported	Not reported		Not reported
George 2016[94]	Singapore	340	72.6±9.1		11.8%
Gerber 2018[95]	Australia	381	71±12		39.9%
Gerrits 2003[96]	Netherlands	1219		65–74	40.4%
Gulati 2018[106]	USA	250	69±11		42.0%
Ingadottir 2018[118]	Iceland	99		73.0 (71.0–77.0)	54.5%
Ingadottir 2018[117]	Iceland	121	73.7±9.0		57.0%
Jeffs 2005[124]	Australia	216	67.5		63.9%
Joyner 2022[131]	USA	253	73.6±7.1		65.2%
Kawasumi 2013[133]	Canada	3723	72.8		50.8%
Kim 2020[138]	USA	65	62.5±9.0		58.5%
Kiri 2005[141]	UK	2557	71.1±9.0		49.6%
Kiser 2019[142]	USA	28,700		60–69	53.9%
Ko 2014[147] Ko 2021[148]	Hong Kong	185	76.9±7.37		10.3%
Lalmolda 2017[149]	Spain	48	72.5±7.2		6.2%
LaRoche 2016[150]	USA	3024	Not reported		Not reported
Lee 2016[153]	USA	995	67.3±10.5		52.6%
Matsui 2017[163]	Japan	12,572	78.4±9.5		18.7%
McGurran 2019[164]	USA	2885	70.5±11.5		46.9%

(Continued)

Table 2 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Moullec 2012[166]	Canada	189	72.1±10.4	[redacted]	50.3%
Myers 2020[169]	USA	805,764	Not reported	[redacted]	56.3%
Nguyen 2014[175]	USA	4596	72.3±10.8	[redacted]	Not reported
Nguyen 2021[174]	USA	128	64.6±9.2	[redacted]	56.3%
Ohar 2018[179]	USA	1274	Not reported	[redacted]	56.3%
Pant 2020[183]	Nepal	86	70.6±11.0	[redacted]	47.7%
Parikh 2016[184]	USA	44	66	[redacted]	40.9%
Pendharkar 2018[186]	Canada	1435	70±12	[redacted]	48.5%
Petite 2020[188]	USA	358	67.1±11.6	[redacted]	60.9%
Pitta 2006[190]	Belgium	17	[redacted]	69 (60–78)	5.9%
Puebla Neira 2021[197]	USA	4,587,542	Not reported	[redacted]	42.2%
Revitt 2013[200]	UK	160	70.4±8.6	[redacted]	45.6%
Rueda-Camino 2017[211]	Spain	87	70.4±9.3	[redacted]	11.5%
Russo 2017[212]	USA	160	65.9±10.0	[redacted]	52.5%
Seys 2018[213]	European countries	257	69.8±10.3	[redacted]	33.9%
Sharma 2010[217]	USA	62,746	[redacted]	75–84	58.6%
Shi 2018[219]	China	6333	67.5±9.5	[redacted]	Not reported
Shin 2019[220]	South Korea	308	72.3±9.5	[redacted]	23.7%
Sin 2001[222]	Canada	22,620	75.1±6.7	[redacted]	43.5%
Sonstein 2014[226]	USA	420	66.5±11.2	[redacted]	49.5%
Stefan 2013[227]	USA	53,900	[redacted]	70 (61–78)	58.0%
Stefan 2021[229]	USA	197,376	76.9±7.6	[redacted]	58.6%
Suh 2015[233]	England	120	70±9	[redacted]	51.7%
van Eeden 2017[238]	Netherlands	10	62.9±9.6	[redacted]	80.0%
Werre 2015[243]	USA	244	Not reported	[redacted]	Not reported
Zafar 2019[252]	USA	Not reported	Not reported	[redacted]	Not reported
Zafar 2020[251]	USA	133	60.0±9.8	[redacted]	36.1%
Randomized Controlled Trials					
Atwood 2022[28]	Canada	3710	71.7±12.4	[redacted]	49.7%
Benzo 2016[37]	USA	215	68.0±9.5	[redacted]	54.9%
Bucknall 2012[47]	UK	464	69.1±9.3	[redacted]	63.4%
Conti 2002[63]	Italy	49	71.8±7.8	[redacted]	Not reported

(*Continued*)

Table 2 (Continued).

Study	Country	n	Age (years)		% Female
			Mean ± SD	Median (IQR)	
Criner 2018[67]	USA	64	61.7±7.9		60.9%
De Jong 2007[73]	Netherlands	210	70.7±8.4		25.3%
Deutz 2021[75]	USA	214	74.8±7.3		52.8%
Eaton 2006[77]	New Zealand	78	77.3±7.1		53.8%
Eaton 2009[78]	New Zealand	97	69.9±9.8		56.7%
Garcia-Aymerich 2007[88]	Spain	113	73±8		14.2%
Gunen 2007[107]	Turkey	159	64.1±8.9		12.0%
Hegelund 2020[113]	Denmark	100		73 (45–89)	58.0%
Ip 2004[119]	Hong Kong	130	80.5±6.6		0.0%
Jennings 2015[125]	USA	172	64.7±10.6		55.2%
Jimenez 2021[126]	Spain	737	70.4±9.9		26.5%
Kebede 2022[134]	Norway	40	73.8±8.2		62.5%
Khosravi 2020[137]	Iran	60	71.0±8.9		28.3%
Ko 2011[146]	Hong Kong	60	73.6±7.0		1.7%
Ko 2017[145]	Hong Kong	180	74.8±8.2		4.4%
Ko 2021[148]	Hong Kong	136	75.0±7.6		2.9%
Lellouche 2016[154]	Canada	50	72±8		46.0%
Li 2020[155]	China	378	66.3±8.1		15.9%
Monreal 2016[165]	Spain	120		71 (61–78)	33.3%
Ozturk 2020[181]	Turkey	61	62.5±8.6		11.5%
Pourrashid 2018[193]	Iran	62	63.4±8.5		16.1%
Stolz 2007[230]	Switzerland	226	69.5		50.4%
Struik 2014[231]	Netherlands	201	63.7±8.3		58.7%
Utens 2012[237]	Netherlands	139	68.0±10.8		38.1%
Vanhaecht 2016[239]	European countries	342	69.9±10.3		32.2%
Vermeersch 2019[240]	Belgium	301	65.5±9.5		43.9%
Wang 2016[241]	China	191	72.9±9.6		28.3%
Xia 2022[248]	China	337		70.0 (65.0–75.0)	16.9%

Note: Blacked out cells indicate that data are not available/applicable.

(Figure 4b). Longer hospital length of stay, higher eosinophil count, and home oxygen after discharge were also frequently reported predictors of readmission (Figure 4c and e). Degrees of significance, and the specific studies reporting on each significant predictor, are reported in Table 4.

Six prediction scores – the BODEX index,[23] CODEX index,[23] CORE score,[247] DOSE index,[23] PEARL score,[143] and RACE scale[151] – were reported to be predictive of all-cause readmission. The included components of each prediction score are reported in Table 5. CORE, PEARL, and RACE were reported to have good predictive value for readmission as a time-to-event outcome variable. The BODEX index, CODEX index, and DOSE index were reported to have good predictive ability for 2–3-month readmission. The CODEX index was reported to have good predictive ability for 6–12-month readmission (Table 3).

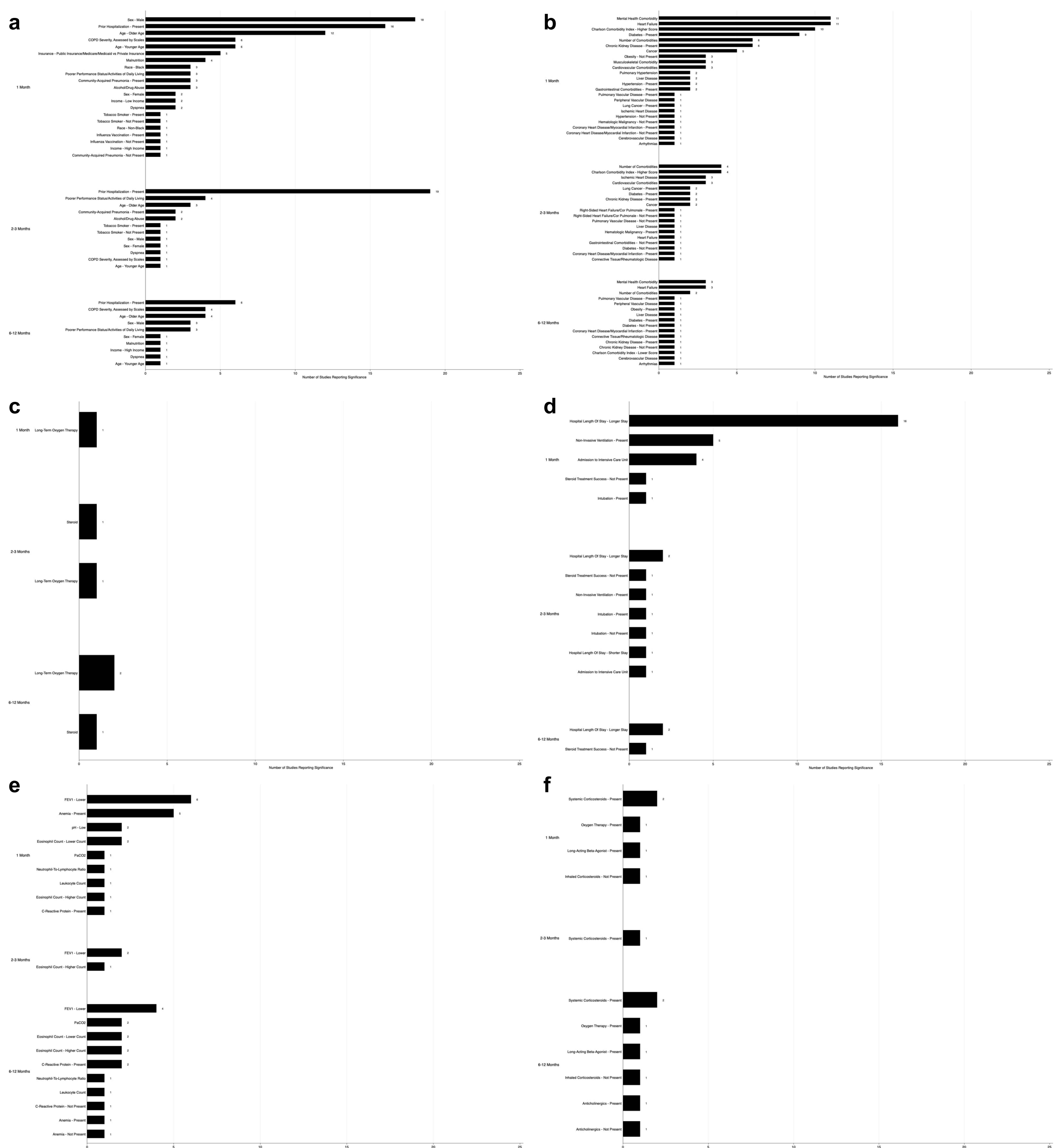

Figure 3 Continued.

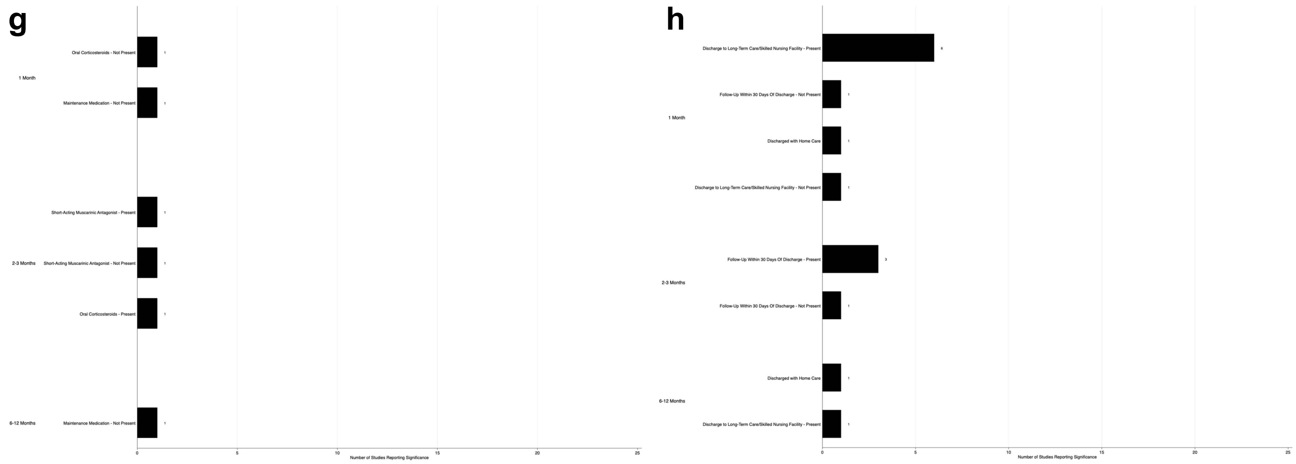

Figure 3 Significant predictors of all-cause readmission: (**a**) patient characteristics; (**b**) comorbidities; (**c**) medications prior to admission; (**d**) hospital care; (**e**) investigations; (**f**) medications during hospitalization; (**g**) medications on discharge; (**h**) disposition.

Some studies reported significant interventions that can reduce all-cause and COPD-related readmission, most notably use of a COPD-specific care package (Supplementary Tables 3 and 4). Most studies reporting on interventions reported that their intervention was not associated with a significant reduction in readmission rates.

Discussion

This is the largest systematic review to date, reporting on predictors for readmission of patients with COPD, with 242 articles reporting on 16,471,096 patients included in this review. We comprehensively report on predictors for both all-cause and COPD-related readmissions, for readmission at 1 month, 2–3 months, and 6–12 months. The included studies originated from around the world, and there was generally a low risk of bias. There were 64 predictors for all-cause readmission and 23 predictors for COPD-specific readmission. Significant predictors for all-cause readmissions included 1) pre-admission patient characteristics, such as male sex, prior hospitalization, poor performance status, number and type of comorbidities, and use of long-term oxygen; 2) hospitalization details, such as length of stay, use of corticosteroids, and use of ventilatory support; 3) results of investigations, including anemia, lower FEV_1, and higher eosinophil count; and 4) discharge characteristics, including the use of home oxygen and discharge to long-term care or a skilled nursing facility.

Several prior systematic reviews have also reported on predictors. Alqahtani et al reviewed 14 studies, stating that comorbidities, previous exacerbations/hospitalizations, and increased length of initial hospital stay were major risk factors for 30- and 90-day all-cause readmission.[8] Heart failure, renal failure, depression, and alcohol use were also associated with increased 30-day all-cause readmission, with being female described as a protective factor for readmission. Bahadori and Fitzgerald examined 17 studies, and found that previous hospital admission, dyspnea, and oral corticosteroids were significant risk factors for readmission.[9] Njoku et al reviewed 57 studies, and found that hospitalization in the year prior to index admission, comorbidities (such as asthma), living in a deprived area, and living in/or discharge to a nursing home were key predictors of COPD-related readmission.[10]

This review identifies some notable predictors worth highlighting that are not contained in previous studies, which were parsimonious. While prior studies reported heart failure and neuromuscular disease, we identified other significant preadmission comorbidities, including alcohol use, diabetes, and mental health. Similarly, poor performance status and malnutrition were both identified as important predictors of readmission. In-hospital use of critical care, including non-invasive ventilation, invasive ventilation, and ICU stay, was also identified as predictors. Use of steroids was also predictive of readmission; this was probably related to the severity of disease. Eosinophil count was both correlated and inversely correlated in different studies. While all studies excluded corticosteroid use prior to measurement of the

Table 3 Significant Predictors for All-Cause Readmission

Variable Type	Type I Error	1 Month	2–3 Months	6–12 Months
Patient Characteristics				
Age	<0.05	Correlated[29,53,105,172] Inversely correlated[191]	Correlated[38] Inversely correlated[183]	Correlated[53,66,127]
	<0.01	Correlated[33,49,50,123,185,233,253] Inversely correlated[34,122,151,214,221]	Correlated[111,123]	Correlated[123] Inversely correlated[76]
	Not reported	Correlated[29]		
Alcohol/drug abuse	<0.05	Correlated[29]		
	<0.01	Correlated[49,224]	Correlated[34,205]	
	Not reported			
Community-acquired pneumonia	<0.05	Correlated[83,210] Inversely correlated[208]	Correlated[254]	
	<0.01	Correlated[50]	Correlated[50]	
	Not reported			
COPD severity, assessed by scales	<0.05			
	<0.01	Correlated[25,49,50,105,247,250]	Correlated[50]	Correlated[53,55,127,244]
	Not reported			
Dyspnea	<0.05	Correlated[54]	Correlated[38]	Correlated[84]
	<0.01	Correlated[105]		
	Not reported			
Income	<0.05	Correlated[215]		
	<0.01	Inversely correlated[122,224]		Correlated[97]
	Not reported			
Insurance: public insurance/Medicare/Medicaid vs private insurance	<0.05			
	<0.01	Correlated[49,53,122,128,151]		
	Not reported			

(*Continued*)

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Table 3 (Continued).

Variable Type	Type I Error	1 Month	2–3 Months	6–12 Months
Male	<0.05	Correlated[16,35,151,172,178,215,216] Inversely correlated[123]	Inversely correlated[123]	Correlated[59] Inversely correlated[123]
	<0.01	Correlated[49,53,74,122,128,140,185,214,224,232] Inversely correlated[253]	Correlated[195]	Correlated[41,76]
	Not reported	Correlated[201]		
Malnutrition	<0.05	Correlated[74]		Correlated[139]
	<0.01	Correlated[33,74,253]		
	Not reported			
Poorer performance status/activities of daily living	<0.05	Correlated[25,84,247]	Correlated[25,195,198]	Correlated[30,84,104]
	<0.01		Correlated[62]	
	Not reported			
Prior hospitalization	<0.05	Correlated[54,84,178,212,233]	Correlated[20,38,178,183]	Correlated[178]
	<0.01	Correlated[25,31,49,105,125,172,175,176,208,215,216]	Correlated[22,25,31,45,84,89,91,111,125,195,198,209,212,215]	Correlated[41,55,81,87,104]
	Not reported		Correlated[62]	
Race: black	<0.05	Inversely correlated[172]		
	<0.01	Correlated[102,151,214]		
	Not reported			
Tobacco smoker	<0.05	Correlated[247]	Correlated[45]	
	<0.01	Inversely correlated[253]	Inversely correlated[38]	
	Not reported			
Vaccination: influenza	<0.05	Correlated[170]		
	<0.01	Inversely correlated[232]		
	Not reported			

Comorbidities				
Number of comorbidities	<0.05	Correlated[29,34,35,123,172]	Correlated[38,123]	Correlated[123]
	<0.01	Correlated[122]	Correlated[34,205]	Correlated[244]
	Not reported			
Arrhythmias	<0.05	Correlated[24]		Correlated[56]
	<0.01			
	Not reported			
Cancer	<0.05		Correlated[31]	
	<0.01	Correlated[31,33,49,50,253]	Correlated[50]	
	Not reported			
Cardiovascular comorbidities	<0.05	Correlated[34,103]	Correlated[38,198]	
	<0.01	Correlated[49]	Correlated[34]	
	Not reported			
Cerebrovascular disease	<0.05			
	<0.01	Correlated[49]		Correlated[31]
	Not reported			
Charlson comorbidity index	<0.05	Correlated[74,215,255]	Correlated[195,215]	Inversely correlated[178]
	<0.01	Correlated[33,50,128,175,176,214,253]	Correlated[50,111]	
	Not reported			
Chronic kidney disease	<0.05	Correlated[54]	Correlated[31]	Inversely correlated[76]
	<0.01	Correlated[33,49,50,122,250]	Correlated[50]	Correlated[31]
	Not reported			
Connective tissue/rheumatologic disease	<0.05			Correlated[31]
	<0.01		Correlated[208]	
	Not reported			

(*Continued*)

Table 3 (Continued).

Variable Type	Type I Error	1 Month	2–3 Months	6–12 Months
Coronary heart disease/myocardial infarction	<0.05		Correlated[31]	
	<0.01	Correlated[49] Inversely correlated[255]		Correlated[31]
	Not reported			
Diabetes	<0.05	Correlated[212,232]	Correlated[31,205] Inversely correlated[111]	Correlated[108]
	<0.01	Correlated[31,33,49,122,151,176,232]		Correlated[30]
	Not reported			
Gastrointestinal comorbidities	<0.05	Correlated[212]	Inversely correlated[208]	
	<0.01	Correlated[49]		
	Not reported			
Heart failure	<0.05	Correlated[24,29,216,232]		Correlated[56,108]
	<0.01	Correlated[31,33,49,122,176,250,253]	Correlated[31]	Correlated[31]
	Not reported			
Right-sided heart failure/cor pulmonale	<0.05		Inversely correlated[208]	
	<0.01		Correlated[205]	
	Not reported			
Hematologic malignancy	<0.05			
	<0.01	Inversely correlated[208]	Correlated[208]	
	Not reported			
Hypertension	<0.05	Correlated[212,232]		
	<0.01	Inversely correlated[49]		
	Not reported			

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Ischemic heart disease	<0.05	Correlated[232]	Correlated[20]	
	<0.01		Correlated[50,205]	
	Not reported			
Liver disease	<0.05			Correlated[31]
	<0.01	Correlated[31,49]	Correlated[31]	
	Not reported			
Lung cancer	<0.05			
	<0.01	Correlated[50,216]	Correlated[50,205]	
	Not reported			
Mental health comorbidity	<0.05	Correlated[25,29,176]		Correlated[66,97,108]
	<0.01	Correlated[14,49,83,151,216,224,232,250]		
	Not reported			
Musculoskeletal comorbidity	<0.05			
	<0.01	Correlated[216,232,247]		
	Not reported			
Obesity	<0.05			Correlated[84]
	<0.01	Inversely correlated[74,122,253]		
	Not reported			
Peripheral vascular disease	<0.05			
	<0.01	Correlated[49]		Correlated[31]
	Not reported			
Pulmonary hypertension	<0.05			
	<0.01	Correlated[176,250]		
	Not reported			

(*Continued*)

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Table 3 (Continued).

Variable Type	Type I Error	1 Month	2–3 Months	6–12 Months
Pulmonary vascular disease	<0.05		Inversely correlated[208]	
	<0.01	Correlated[250]		Correlated[56]
	Not reported			
Medications Prior to Admission				
Long-term oxygen therapy	<0.05	Correlated[24]	Correlated[183]	Correlated[100]
	<0.01			Correlated[104]
	Not reported			
Steroid	<0.05		Correlated[215]	Correlated[244]
	<0.01			
	Not reported			
Hospital Care				
Admission to ICU	<0.05	Correlated[172,224,250]	Correlated[183]	
	<0.01	Correlated[214]		
	Not reported			
Hospital length of stay	<0.05	Correlated[25,33,172,216,224,250]	Correlated[38] Inversely correlated[183]	Correlated[76,104]
	<0.01	Correlated[49,50,105,122,128,140,185,202,214,253]	Correlated[50]	
	Not reported			
Intubation	<0.05		Inversely correlated[208]	
	<0.01	Correlated[49]	Correlated[111]	
	Not reported			
Non-invasive ventilation	<0.05	Correlated[74,212]		
	<0.01	Correlated[33,49,247]	Correlated[38]	
	Not reported			

Steroid treatment success	<0.05	Inversely correlated[69]		Inversely correlated[69]
	<0.01		Inversely correlated[69]	
	Not reported			
Investigations				
Anemia	<0.05			Correlated[108] Inversely correlated[76]
	<0.01	Correlated[33,49,175,176,250]		
	Not reported			
C-reactive protein	<0.05	Correlated[60]		
	<0.01			Correlated[53,127] Inversely correlated[76]
	Not reported			
Eosinophil count	<0.05	Inversely correlated[135,199]	Correlated[114]	Correlated[65] Inversely correlated[76,156]
	<0.01	Correlated[247]		Correlated[114]
	Not reported			
FEV_1	<0.05	Inversely correlated[204,235,249]	Inversely correlated[89,182]	Inversely correlated[66]
	<0.01	Inversely correlated[105,212,247]		Inversely correlated[53,87,104]
	Not reported			
Leukocyte count	<0.05			
	<0.01	Correlated[60]		Correlated[76]
	Not reported			
Neutrophil-to-lymphocyte ratio	<0.05			
	<0.01	Correlated[60]		Correlated[76]
	Not reported			

(*Continued*)

https://doi.org/10.2147/COPD.S418295

Table 3 (Continued).

Variable Type	Type I Error	1 Month	2–3 Months	6–12 Months
$PaCO_2$	<0.05			Correlated[100,139]
	<0.01	Correlated[105]		
	Not reported			
pH	<0.05	Inversely correlated[105,255]		
	<0.01			
	Not reported			
Medications During Hospitalization				
Anticholinergics	<0.05			Correlated[87]
	<0.01			Inversely correlated[104]
	Not reported			
Inhaled corticosteroids	<0.05			
	<0.01	Inversely correlated[208]		Inversely correlated[55]
	Not reported			
Oxygen therapy	<0.05			
	<0.01	Correlated[175]		Correlated[31]
	Not reported			
Long-acting beta-agonist	<0.05	Correlated[176]		
	<0.01			Correlated[55]
	Not reported			
Systemic corticosteroids	<0.05	Correlated[175]		
	<0.01	Correlated[176]	Correlated[31]	Correlated[31,76]
	Not reported			
Medications on Discharge				
Oral corticosteroids	<0.05	Inversely correlated[216]	Correlated[195]	
	<0.01			
	Not reported			

Maintenance medication	<0.05	Inversely correlated[232]		
	<0.01			Inversely correlated[234]
	Not reported			
Short-acting muscarinic antagonist	<0.05			
	<0.01		Correlated[208] Inversely correlated[208]	
	Not reported			
Disposition				
Discharged with home care	<0.05			Correlated[81]
	<0.01	Correlated[214]		
	Not reported			
Discharged to long-term care/skilled nursing facility	<0.05	Correlated[74,232] Inversely correlated[224]		Correlated[108]
	<0.01	Correlated[35,49,122,128]		
	Not reported			
Follow-up within 30 days of discharge	<0.05		Correlated[125] Inversely correlated[91]	
	<0.01	Inversely correlated[216]	Correlated[182,198]	
	Not reported			
Prediction Scores				
BODEX index[23]			p=0.008	
CODEX index[23]			p<0.0001	p<0.0001
CORE score[247]	p<0.001			
DOSE index[23]			p<0.01	
PEARL score[143]	p<0.0001			
RACE scale[151]	R^2=0.923			

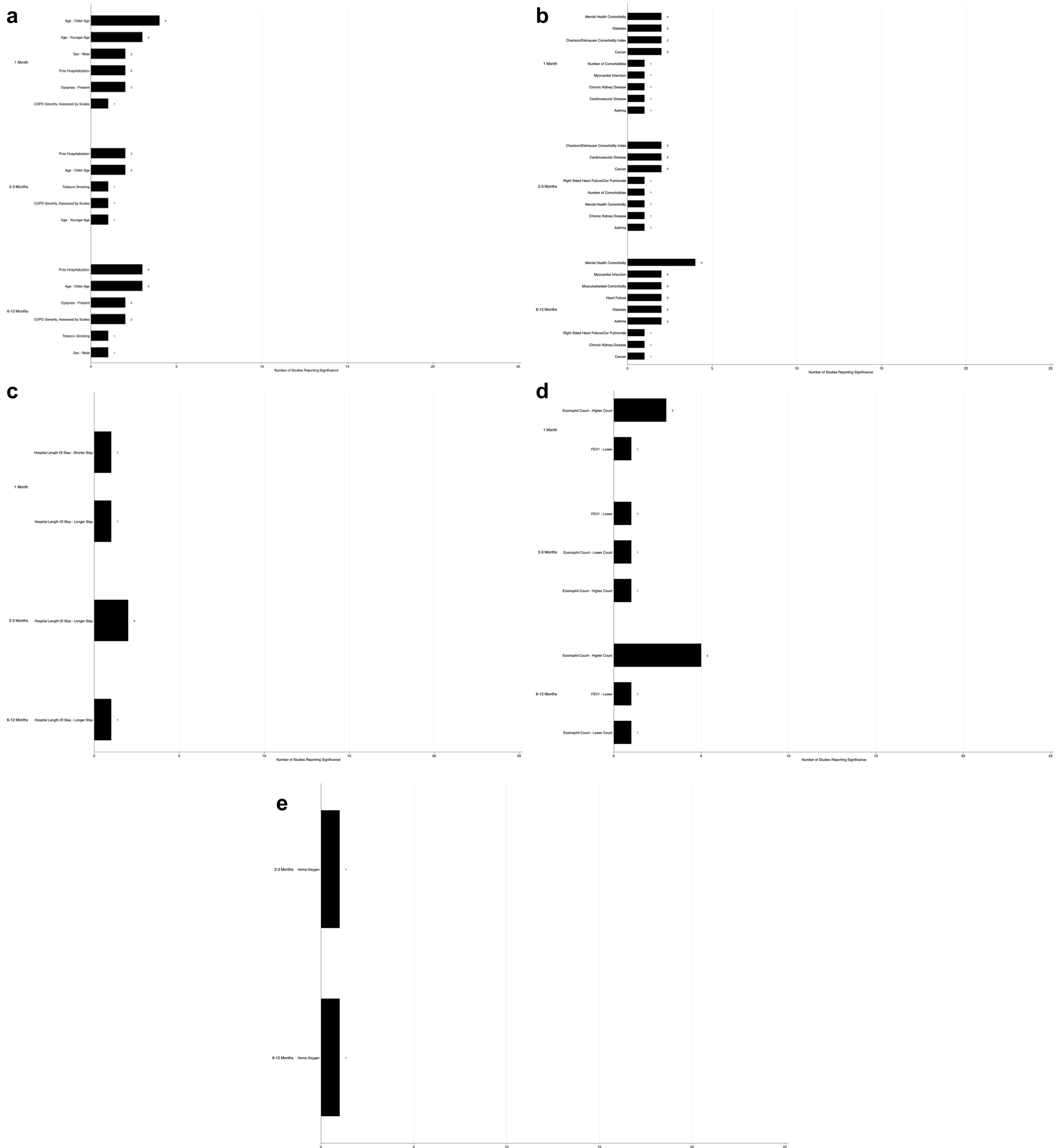

Figure 4 Significant predictors of COPD-related readmission: (**a**) patient characteristics; (**b**) comorbidities; (**c**) hospital care; (**d**) investigations; (**e**) medications on discharge.

eosinophil count, the studies used various cut-offs to define eosinopenia.[114,135,199,247] Further research to determine the utility of eosinophil count is needed.

With COPD patients having a high all-cause readmission rate of 50%[5] and being the largest single group of chronic disease patients reported in the literature, identifying those at greatest risk of readmission is a priority as more resources can be directed to this group. This comprehensive systematic review identifies many predictors across multiple domains, including prior to admission, during hospitalization, and post-hospitalization. Current prediction rules for readmissions

Table 4 Significant Predictors of COPD-Related Readmission

	Type I Error	I Month	2–3 Months	6–12 Months
Patient Characteristics				
Age	<0.05	Correlated[219,245]		Correlated[31,129,234]
	<0.01	Correlated[50,110] Inversely correlated[34,48,206]	Correlated[50,110] Inversely correlated[34]	
	Not reported			
COPD severity, assessed by scales	<0.05			Correlated[21,187]
	<0.01	Correlated[50]	Correlated[50]	
	Not reported			
Dyspnea	<0.05	Correlated[116]		Correlated[21]
	<0.01	Correlated[206]		Correlated[206]
	Not reported			
Male	<0.05			Correlated[129]
	<0.01	Correlated[48]		
	Not reported	Correlated[201]		
Prior hospitalization	<0.05			Correlated[129]
	<0.01	Correlated[31,70]	Correlated[22,31]	Correlated[21,31]
	Not reported			
Tobacco smoking	<0.05			
	<0.01		Correlated[34]	Correlated[206]
	Not reported			
Comorbidities				
Number of comorbidities	<0.05			
	<0.01	Correlated[219]	Correlated[34]	
	Not reported			
Asthma	<0.05			Correlated[129]
	<0.01	Correlated[206]	Correlated[50]	Correlated[206]
	Not reported			
Cancer	<0.05	Correlated[31,50]	Correlated[31,50]	
	<0.01			Correlated[31]
	Not reported			
Cardiovascular disease	<0.05	Correlated[34]	Correlated[34]	
	<0.01		Correlated[135]	
	Not reported			

(*Continued*)

Table 4 (Continued).

	Type I Error	I Month	2–3 Months	6–12 Months
Charlson/Elixhauser comorbidity index	<0.05		Correlated[22]	
	<0.01	Correlated[48,50]	Correlated[50]	
	Not reported			
Chronic kidney disease	<0.05			
	<0.01	Correlated[50]	Correlated[50]	Correlated[31]
	Not reported			
Diabetes	<0.05	Correlated[206]		
	<0.01	Correlated[70]		Correlated[31,206]
	Not reported			
Heart failure	<0.05			
	<0.01			Correlated[31,206]
	Not reported			
Right-sided heart failure/cor pulmonale	<0.05			Correlated[21]
	<0.01		Correlated[22]	
	Not reported			
Mental health comorbidity	<0.05			Correlated[21,129]
	<0.01	Correlated[121,206]	Correlated[121]	Correlated[121,206]
	Not reported			
Musculoskeletal comorbidity	<0.05			Correlated[129]
	<0.01			Correlated[206]
	Not reported			
Myocardial infarction	<0.05			
	<0.01			Correlated[31,129]
	Not reported	Correlated[99]		
Hospital Care				
Hospital length of stay	<0.05	Inversely correlated[110]		Correlated[187]
	<0.01	Correlated[50]	Correlated[50,110]	
	Not reported			
Investigations				
Eosinophil count	<0.05	Correlated[114]		Correlated[112] Inversely correlated[156]
	<0.01	Correlated[114,245]	Correlated[114] Inversely correlated[135]	Correlated[36,65,114,187]
	Not reported			

(*Continued*)

Table 4 (Continued).

	Type I Error	I Month	2–3 Months	6–12 Months
FEV_1	<0.05			
	<0.01	Inversely correlated[34]	Inversely correlated[34,135]	Inversely correlated[245]
	Not reported			
Medications During Admission				
Oxygen therapy	<0.05			
	<0.01	Inversely correlated[185]		Correlated[31]
	Not reported			
Medications on Discharge				
Home oxygen	<0.05			Correlated[21]
	<0.01		Correlated[22]	
	Not reported			

Table 5 Characteristics of Prediction Scores

	CODEX	BODEX	PEARL	CORE	RACE
Patient characteristics	Comorbidity Number of severe exacerbations (ED or admission) mMRC scale	BMI Number of severe exacerbations (ED or admission) mMRC scale	Age Previous admissions Left heart failure/ right heart failure eMRC scale Right heart failure	Lung function Neuromuscular disease exacerbations Triple inhaler management	Age Gender Income Race Payer Comorbidities
Hospitalization management	–	–	–	–	
In-hospital investigations	FEV_1%	FEV_1%		Eosinophil count	
Discharge characteristics	–	–	–	–	

have areas under the receiver operating characteristics curve in the range 0.70–0.72, and may be limited by lacking variables in all domains (Table 5). The findings from this systematic review can be used to develop other prediction scores with higher predictive power. The findings can also be used in clinical practice to help identify individual patients who may benefit from more resources to reduce their risk of readmission. While most prediction scores for COPD readmission are parsimonious, having five or fewer variables for ease of use, a more complicated model with more predictors may be more accurate. More complex models may be enabled through the increase in electronic patient records, which enable more discrete data elements as well as computer decision support.[256]

This review was not without limitations. There was heterogeneous reporting on some predictor variables; many studies used different cut-off points for predictor variables. We therefore reported on the general directionality of a predictor variable as it relates to readmission. We have reported the predictors as reported by the studies, using their original cut-off points and without any synthesis, in Supplementary Tables 1 and 2. In addition, we were unable to report non-significant predictors owing to non-uniform reporting and therefore the total number of studies investigating each predictor. It is therefore unclear how many studies investigated specific predictors, and what proportion of them reported significant correlation with readmission. For certain predictors that may not be as well studied (eg malnutrition), there could be underestimation of importance.

It is also important to note that some published literature suggests that not all patients discharged with a diagnosis of "COPD" have spirometrically confirmed COPD, and therefore patients discharged with "COPD" may in fact have other comorbidities, such as congestive heart failure.[257] Therefore, caution is needed in the interpretation of some of the included studies, given that they simply included patients with a diagnosis of COPD which may not necessarily be confirmed on spirometry. Future studies could look to assess only patients who have spirometrically confirmed COPD.

There may also be some concerns over the generalizability of individual studies to the larger population of patients with COPD admitted to hospitals. There were three studies[127,190,238] with sample sizes of less than 20, and another three studies[80,134,194] with sample sizes of 20–40 patients. Moreover, there were three studies[98,119,210] with no females included in the sample, and another 52 studies[20–23,29,32,38,42,51,53,68–70,72,74,88,90,91,94,116,139,143–149,155,159,161–163,173,177,181,182,190,192,193,201–203,209,211,245,247,249,255] where less than 20% of the sample comprised of females. Reassuringly, the significant predictors reported by these studies agree with larger and more representative studies. In addition, a large proportion of the studies originated from the USA, which may make the results of this review more generalizable to the US population and slightly less generalizable to other countries, especially given the lack of a universal healthcare system in the USA and therefore the potential confounding effect on readmissions.

In conclusion, we found that predictors of readmissions after an admission for COPD exacerbation included patient characteristics prior to and at admission, hospitalization management, results from admission investigations, and discharge characteristics. Findings from this review may enable better model generation if predictors from all these domains are included. These findings may also be used to identify new predictors in the different domains and can be used by clinicians to help generate their gestalt of readmission.

Disclosure

The authors report no conflicts of interest in this work.

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