



OPEN ACCESS

Original research

Quantifying sustained health system benefits of primary care-based integrated disease management for COPD: a 6-year interrupted time series study

Christopher Liciskai,^{1,2,3} Anna Hussey ,³ Véronique Rowley,⁴ Madonna Ferrone,^{3,5} Zihang Lu,⁴ Kimball Zhang,^{6,7} Emilie Terebessy,⁶ Andrew Scarffe,⁸ Shannon Sibbald,⁹ Cathy Faulds,^{1,3} Tim O'Callahan,^{3,10} Teresa To^{6,7}

► Additional supplemental material is published online only. To view, please visit the journal online (<https://doi.org/10.1136/thorax-2023-221211>).

For numbered affiliations see end of article.

Correspondence to

Dr Christopher Liciskai, Western University Schulich School of Medicine & Dentistry, London, ON N6A 5C1, Canada; Chris.Liciskai@sjhc.london.on.ca

Received 17 November 2023

Accepted 16 May 2024

Published Online First

18 June 2024

ABSTRACT

Background Severe exacerbation of chronic obstructive pulmonary disease (COPD) is a trajectory-changing life event for patients and a major contributor to health system costs. This study evaluates the real-world impact of a primary care, integrated disease management (IDM) programme on acute health service utilisation (HSU) in the Canadian health system.

Methods Interrupted time series analysis using retrospective health administrative data, comparing monthly HSU event rates 3 years prior to and 3 years following the implementation of COPD IDM. Primary outcomes were COPD-related hospitalisation and emergency department (ED) visits. Secondary outcomes included hospital bed days and all-cause HSU.

Results There were 2451 participants. COPD-related and all-cause HSU rates increased in the 3 years prior to IDM implementation. With implementation, there was an immediate decrease (month 1) in COPD-related hospitalisation and ED visit rates of -4.6 (95% CI: -7.76 to -1.39) and -6.2 (95% CI: -11.88 , -0.48) per 1000 participants per month, respectively, compared with the counterfactual control group. After 12 months, COPD-related hospitalisation rates decreased: -9.1 events per 1000 participants per month (95% CI: -12.72 , -5.44) and ED visits -19.0 (95% CI: -25.50 , -12.46). This difference nearly doubled by 36 months. All-cause HSU also demonstrated rate reductions at 12 months, hospitalisation was -10.2 events per 1000 participants per month (95% CI: -15.79 , -4.44) and ED visits were -30.4 (95% CI: -41.95 , -18.78).

Conclusions Implementation of COPD IDM in a primary care setting was associated with a changed trajectory of COPD-related and all-cause HSU from an increasing year-on-year trend to sustained long-term reductions. This highlights a substantial real-world opportunity that may improve health system performance and patient outcomes.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a heterogeneous lung disease that causes persistent and often progressive airflow limitation.¹ It is characterised by chronic symptoms, notably dyspnoea, cough and sputum production.^{1 2} Globally, there were over 212 million people living with COPD in 2019, attributing 3.3 million deaths and accruing

WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Globally, the care of patients with chronic obstructive pulmonary disease (COPD) is characterised by low guideline concordance and high rates of acute health services use including hospitalisation and emergency department (ED) visits.
- ⇒ Randomised controlled trials have confirmed the efficacy of integrated disease management (IDM), a cost-effective, team-based approach to improve concordance between clinical care and clinical practice guidelines, to reduce acute health service utilisation.
- ⇒ Although a majority of patients with COPD are managed in the community in primary care, the effectiveness of COPD IDM has not been examined in a real-world primary care setting.

WHAT THIS STUDY ADDS

- ⇒ Primary care-based COPD IDM is an effective intervention, and implementation was associated with a change in disease trajectory from increasing acute health service utilisation, to an immediate and sustained long-term reduction in hospitalisation and ED visits.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Strong supporting evidence for the real-world effectiveness of COPD IDM highlights that a substantial opportunity to improve health system performance and patient outcomes may exist, warranting IDM evaluation in different settings globally.

74.4 million disability-adjusted life years.³ Exacerbation, characterised by moderate or severe symptom worsening, is a substantial burden to both patients and health systems.^{1 2} Inpatient hospital admissions are responsible for the greatest proportion of direct economic costs and heighten the risk of subsequent severe exacerbation and mortality.^{1 2 4-8} In addition, people with COPD exhibit a higher prevalence of disease comorbidity than those without, further increasing health system utilisation and expenditure.^{1 9-11} These hospitalisation rates have persisted over time in multiple health jurisdictions



► <http://dx.doi.org/10.1136/thorax-2024-221754>



© Author(s) (or their employer(s)) 2024. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

To cite: Liciskai C, Hussey A, Rowley V, et al. *Thorax* 2024;**79**:725–734.

globally and therefore, the implementation of effective solutions is required to improve health system performance.^{7 12}

Integrated disease management (IDM) programmes provide an effective, proactive model of care—formally integrating current evidence-based COPD management guidelines using a multicomponent, multidisciplinary approach involving pharmacological therapies, pulmonary rehabilitation, case management, education and self-management strategies.¹² The goal is to prevent and manage exacerbation effectively thereby improving COPD prognosis and avoiding costly acute care service utilisation.¹ Collectively, randomised controlled trials (RCTs) have demonstrated IDM can reduce respiratory-related hospital admissions and emergency department (ED) visits and improve health-related quality of life (HR-QoL).¹³ Pulmonary rehabilitation is highly effective, but its health system impacts are limited by access, high resource intensity and its waning effect over time.^{1 14 15} This highlights the need for more cost-effective, long-term interventions and continued surveillance to evaluate if health system impacts are sustained over time and across jurisdictions.¹⁶

Best Care COPD is a primary care-based, self-management IDM programme emanating from an RCT that confirmed programme efficacy, including reduced acute health service utilisation (HSU) and improved HR-QoL.¹⁷ Further evaluative studies of the Best Care COPD Programme supported real-world effectiveness, reporting that Best Care improved patient and provider experiences, and that it was cost-effective and dominant relative to the usual standard of care.^{18–23} As with the majority of studies forming a large body of published literature on IDM, the quantitative evaluations were limited to 1 year of locally collected follow-up data.¹³ Additionally, even for pulmonary rehabilitation, a gold-standard COPD IDM intervention, the long-term

impacts are unproven.¹⁵ Considering the substantial multiyear impact that COPD has on health system utilisation, it is imperative to directly evaluate the effect of COPD IDM at the health system level and to extend the evaluation window. Accordingly, we used health administrative data from a publicly funded health system, the Ontario Health Insurance Plan (OHIP), to examine the impact of the Best Care COPD Programme on health system performance, including hospital admissions and ED visits, over a 6-year observation window.

METHODS

Study design

We quantified the impact of Best Care COPD using interrupted time series. HSU events between 13 January 2008 and 31 March 2020 were included. Data beyond 31 March 2020 were excluded to avoid potential bias from the COVID-19 pandemic period. HSU data were retrieved, from provincial health administrative databases, at monthly intervals for the 3 years prior to the initial Best Care appointment and for up to 3 years after or until the participant died. The observation periods for each participant were centred to the initial appointment (T_0). Acute HSU was tracked from -36 months to T_0 (pre-intervention period) and T_0 to $+36$ months (intervention period). Date of initial appointment could therefore occur anytime between 13 January 2011 and 31 March 2019, so every participant had 36 months pre-intervention and a minimum of 12 months of intervention follow-up (figure 1).

Best Care COPD is a structured multidisciplinary IDM programme embedded in primary care across the province of Ontario, Canada. The programme creates a triad of collaborative care between a patient, their primary care provider and a

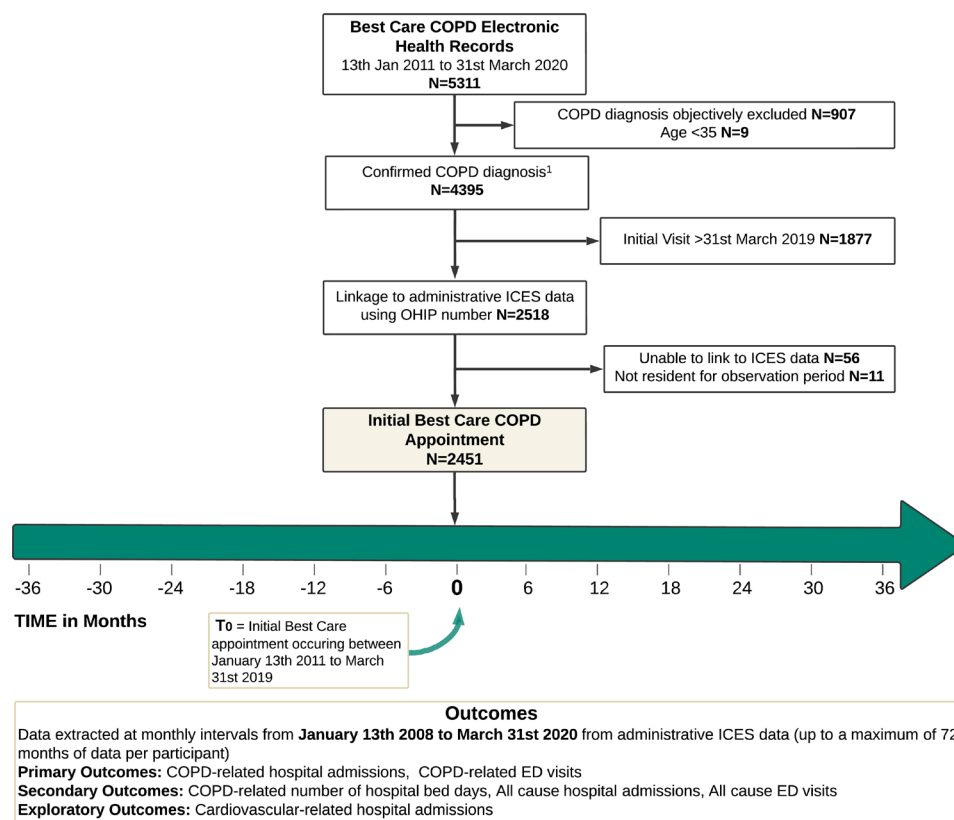


Figure 1 Flow diagram showing participant numbers, exclusion and inclusion, and study timeline. ¹COPD diagnosis at initial visit confirmed clinically or objectively. COPD, chronic obstructive pulmonary disease; ED, emergency department; OHIP, Ontario Health Insurance Plan.

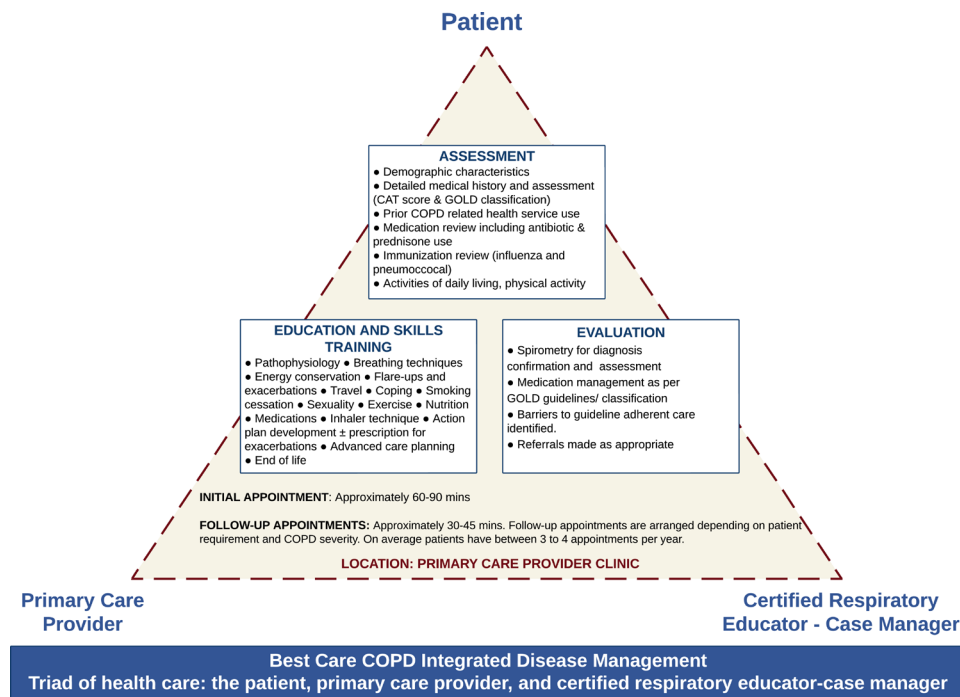


Figure 2 An overview of the Best Care integrated disease management programme. Adapted from Table 1: Ferrone *et al.*¹⁷ and Figure 1: Hussey *et al.*²⁰ CAT, COPD Assessment Test; COPD, chronic obstructive pulmonary disease; GOLD, Global initiative for Obstructive Lung Disease.

certified respiratory educator-case manager. Best Care COPD is a complete knowledge translation module that delivers all elements of evidence-based care that are relevant to primary care including provincial quality standards, national and international COPD guideline recommendations related to diagnosis, comprehensive assessment, individualised care planning, education and self-management, smoking cessation, pharmacological management, vaccinations and referral for specialised respiratory care (figure 2).^{1 2 24} The Best Care Programme elements have been described in detail previously.^{17 20}

Data sources and measurement

Data were collected from two sources: the Best Care COPD IDM electronic health record and ICES (formerly known as the Institute for Clinical Evaluative Sciences).

Best Care COPD IDM

The Best Care COPD health record is an electronic point of service system used as an integrated technology solution that guides and standardises every patient encounter. The digital tool captures health outcomes and measures the achievement of guideline-based performance metrics. The baseline characteristics of all patients were extracted from this registry at T₀ (initial visit). Baseline variables included age, sex, residence (rural vs urban), income (inferred from postal code), body mass index, race, smoking status, smoking pack years, self-reported comorbidities, vaccination status and prior year antibiotic and prednisone use.

COPD-specific baseline variables included: modified Medical Research Council (mMRC) score (0–4) which stratifies the severity of dyspnoea; COPD Assessment Test (CAT) score (0–40), a validated disease-specific quality of life tool that quantifies the impact of COPD symptoms on a patient's overall health; Global initiative for Obstructive Lung Disease (GOLD) (groups ABE) which categorises the severity of COPD using a combination of prior-year exacerbation history and COPD symptoms

using mMRC or CAT; GOLD class (I–IV), a spirometric measure of airflow limitation, post-bronchodilator forced expiratory volume in 1 second.¹

ICES data

Ontario has a publicly funded health system administered under the OHIP. All essential medical services and claims are captured in health administrative databases. ICES houses Ontario health administrative databases, including the National Ambulatory Care Reporting System which captures ED visits, the Canadian Institute for Health Information Discharge Abstract which captures hospital admissions and the Registered Persons Database that records the date of death. Participants were linked by their unique OHIP number to the ICES database. Monthly HSU data were assembled. Primary reason for COPD-related hospital admission or ED visit was identified using the International Classification of Diseases, 10th revision codes. COPD-related HSU was defined as combined COPD-specific HSU and COPD-associated lower respiratory codes, for example 'influenza' or 'pneumonia' (online supplemental table 1E).

Participants

All Best Care Programme patients were included if they were: ≥35 years of age at the initial visit, residents in Ontario for the 3 years prior to commencing the Best Care COPD Programme, had a clinical or objective COPD diagnosis and had attended at least one Best Care appointment (figure 1). Participants were excluded if at any time during follow-up, a COPD diagnosis was objectively ruled out. Censoring occurred when a participant died.

Outcomes

Primary outcomes were COPD-related hospital admissions and COPD-related ED visits. Secondary outcomes included COPD-related hospital bed days, all-cause hospital admissions and

all-cause ED visits. In a post-hoc exploratory analysis, we examined Best Care Programme impacts on cardiovascular (CV)-related hospitalisation.

Statistical analysis

Baseline characteristics of the study population were summarised as the mean and SD for continuous variables and frequency and percentage for categorical variables. In addition, we tabulated annual measures of observed HSU for the 6-year observation window, and mortality events were reported over the 3-year intervention period.

Interrupted time series analysis

Observed monthly HSU rates (events per 1000 participants per month) were calculated over the 6-year observation period. A 3-year pre-intervention and 3-year intervention trend were measured. A 'counterfactual control' was modelled by continuing the pre-intervention trend line through the intervention period, assuming the absence of any intervention (ie, a continuation of usual care). The counterfactual control trend line was compared with the observed intervention trend line. Differences between the counterfactual control and the observed intervention trends were considered as the 'difference-in-difference' in the interrupted time series analysis.

We used a segmented linear regression model to evaluate changes in HSU following the implementation of the IDM programme. Our model included a level change and slope change corresponding to the implementation of the IDM programme (T_0), allowing for the estimation of immediate (level change: T_0 -month 1 of the intervention) and gradual changes (slope change: month 1-month 36) in HSU rates following the intervention. All observations were centred to the initial IDM appointment (T_0) thereby eliminating the effect of seasonality. Estimated intervention effects are reported as absolute changes in HSU rates with 95% CIs.

Sensitivity analysis

We conducted two sensitivity analyses on the counterfactual control for the primary outcomes of COPD-related hospitalisation and ED visits. First, the data were modelled using a constant rate counterfactual control, assuming the rate remained constant from T_0 across the 36-month intervention period.^{25 26} Second, using a counterfactual control modelled from -36 to -13 months of pre-intervention outcome data, thereby eliminating any short-term steep rate elevations observed between -12 and T_0 . An additional sensitivity analysis of the primary outcomes was performed excluding all participants who died, to investigate if a reduction in the most exacerbation-prone individuals due to mortality influenced the observed intervention trend by concentrating on the 'healthier' proportion of the study population.

All analyses were conducted using SAS Enterprise Guide V.8.3.

Patient and public involvement

Best Care has involved patients in programme design and measures patient experience.^{21 27 28} The Patient-Reported Experience Measure in COPD patient experience questionnaire is being implemented.²⁹ As this study is a retrospective administrative dataset evaluation of the Best Care COPD IDM Programme, no patients or members of the public were involved in the conduct of the study.

RESULTS

Participant characteristics

A total of 2518 participants met study entry criteria (figure 1). The mean number of Best Care appointments per participant was 3.4 (SD: ± 2.5) over 12.1 months (± 12.4) of follow-up. COPD pathophysiology, exercise and activity, and medication management are educational components of IDM received by 83.4–93.1% of the study cohort. Skills training in breathing techniques, flare-ups and exacerbation, and inhaler techniques were received by 93–96.5% and case management including action plan development, influenza vaccination and smoking cessation are elements of IDM received by 77.6–100% of the study cohort (online supplemental table 2E). Of the 2518 eligible participants, 2451 were linked to the administrative data and amounted over 13 000 person-years of follow-up (figure 1). The study cohort had a mean age of 67.1 years (± 10.6), with 48.3% female, 98.2% Caucasian and 44.6% in the two lowest income quintiles. This cohort had a mean CAT score of 15.9 (± 8.1), a mean mMRC of 1.4 (± 1.0), 38.4% had two or more comorbidities, 42.2% were GOLD group B and 23.3% GOLD group E (table 1).

Observed HSU and mortality events

Table 2 shows the actual number of events and proportion of individuals experiencing a COPD-related or all-cause HSU in this study cohort. Over 6 years of study evaluation, 3 years pre-intervention and 3 years of intervention, COPD-related hospital admissions ranged from 78 to 283 events per year impacting between 62 (2.5%) and 225 (9.2%) individuals, and amounting to 483–1924 inpatient days. COPD-related ED visits ranged in number from 339 to 809 per year affecting between 205 (11.8%) and 499 (20.4%) individuals. During the intervention period, there were 328 deaths, representing 4.1–6.6% of the study population per year (table 2).

Interrupted time series analysis

COPD-related and all-cause

Figure 3 graphically represents the monthly rates of HSU based on the time series models. Both COPD-related and all-cause HSU demonstrated an increasing trend in the pre-intervention period. During the intervention period, the observed trend remained stable or decreased from T_0 to month 36. In the pre-intervention period, COPD-related hospital admission rates increased by 0.4 events per 1000 per month (95% CI: 0.24 to 0.46), inpatient bed days increased by 2.4 bed days per 1000 per month (95% CI: 1.72 to 3.12) and ED visits by 0.8 events per 1000 per month (95% CI: 0.56 to 0.95). From T_0 to the first month of the intervention period, there was an immediate drop in the event rate (level change) for hospital admissions of -4.6 events per 1000 per month (95% CI: -7.76 to -1.39), -32.7 inpatient bed days per 1000 per month (95% CI: -53.29 to -12.14) and -6.2 ED visits per 1000 per month (95% CI: -11.88 to -0.48). The reduction in rates remained over the 36-month intervention period for all COPD-related HSU events. Similarly, for all-cause HSU, there were increasing rates observed in the pre-intervention period and significant slope reductions in the intervention period, but there was no level change observed from T_0 to month 1 (figure 3 and online supplemental figure 1E for inpatient bed days).

Differences between the counterfactual control and observed trends in the intervention period are quantified at 12, 24 and 36 months in figure 4. For all HSU outcomes, the difference between the counterfactual control and the observed trends increased

Table 1 Baseline demographic and clinical characteristics of the overall study cohort at time of entry into COPD integrated disease management (time 0)

Baseline demographic and clinical characteristics		N=2451
Sex	Male	1266 (51.7%)
	Female	1185 (48.3%)
Age (years)	Mean (SD)	67.1 (10.6)
Residence	Urban	1994 (81.4%)
	Rural	457 (18.6%)
Neighbourhood income quintile*	1 (lowest)	592 (24.2%)
	2	501 (20.4%)
	3	550 (22.4%)
	4	459 (18.7%)
	5 (highest)	344–348†
	Missing	1–5†
Body mass index (kg/m ²)	Mean (SD)	29.4 (7.0)
Race	Caucasian	2408 (98.2%)
Smoking status	Current smoker	985 (40.2%)
	Prior smoker	1284 (52.4%)
	Never smoker	182 (7.4%)
	Pack-years <10	83 (3.4%)
	Pack-years >10	2186 (89.2%)
	Pack-years mean (SD)	42.0 (26.4)
COPD Assessment Test (CAT) (score 0–40)‡	Mean (SD)	15.9 (8.1)
	Missing	443 (18.1%)
Number of comorbidities	0	384 (15.7%)
	1–2	1124 (45.9%)
	>2	943 (38.4%)
mMRC dyspnoea score (0–4)§	Mean (SD)	1.4 (1.0)
GOLD group¶	A	403 (16.4%)
	B	1033 (42.2%)
	E	572 (23.3%)
	Missing	443 (18.1%)
GOLD class**	1 FEV ₁ ≥80%	357 (14.6%)
	2 50%≤FEV ₁ <80%	825 (33.7%)
	3 30%≤FEV ₁ <50%	323 (13.2%)
	4 FEV ₁ <30%	37 (1.5%)
	Missing	909 (37.1%)
Exacerbation-related medication	Prior-year antibiotics	1092 (44.6%)
	Prior-year prednisone	726 (29.6%)
Vaccinations	Influenza	1751 (71.4%)
	Pneumococcal	1531 (62.5%)

*Nearest census-based neighbourhood income quintile, based on postal code at initial visit.

†Small cells have been replaced by a range of values to ensure that data could not be used to reidentify participants. Due to rounding, categorical percentages may not total 100%.

‡A score of 0 indicates a good health-related quality of life, 40 indicates a very poor health-related quality of life.

§A score of 0 indicates little or no effect on breathlessness, 4 indicates a large effect on breathlessness.

¶GOLD A 0–1 exacerbation not leading to hospitalisation, mMRC 0–1 or CAT <10; GOLD B 0–1 exacerbation not leading to hospitalisation, mMRC ≥2 or CAT ≥10; GOLD E ≥2 exacerbation episodes or ≥1 exacerbation leading to hospitalisation.

**GOLD class based on post-bronchodilator FEV₁ (% predicted).

COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 s; GOLD, Global initiative for Obstructive Lung Disease; mMRC, modified Medical Research Council.

through all three time periods. The difference for COPD-related hospital admissions was −9.1 events per 1000 per month (95% CI: −12.72 to −5.44) at month 12 and −18.1 events per 1000 per month (95% CI: −24.39 to −1.78) at month 36. There was a reduction of −61.9 inpatient bed days per 1000 per month (95% CI: −85.39 to −38.36) at 12 months and a further reduction of −120.2 events per 1000 per month (95% CI: −160.92 to −79.48) at 36 months. Likewise, for COPD-related ED visits, the rate difference was −19.0 events per 1000 per month (95% CI: −25.50 to −12.46) at 12 months and −44.6 events per 1000 per month (95% CI: −55.86 to −33.29) at 36 months. Similarly, all-cause HSU events showed significant differences at 12, 24 and 36 months (figure 4 and online supplemental table 3E for inpatient bed days). Estimated annual events avoided are presented in table 3; for COPD-related hospital admissions, the annual reduction ranged from 61 to 84 events per 1000 in year 1 and from 67 to 192 in year 3, and for COPD-related ED visits, there was a respective annual reduction ranging from 107 to 157 and 196 to 465 events per 1000 in year 1 and year 3.

CV-related hospitalisation

There were a total of 116 CV-related hospital admissions, affecting 94 (3.8%) individuals in the year prior to IDM. During the intervention period, there were 128 events in 104 (4.2%) individuals at 12 months and 73 events in 61 (3.5%) individuals at 36 months. At 12, 24 and 36 months, all event rates were significantly reduced compared with the counterfactual control rates: −1.8 per 1000 per month (95% CI: −3.20 to −0.43), −3.32 (95% CI: −5.15 to −1.49) and −4.8 (95% CI: −7.23 to −2.42), respectively (online supplemental tables 3E and 4E).

Sensitivity analyses

Three sensitivity analyses supported the main findings. A standard sensitivity analysis with the counterfactual HSU control held constant from T₀ to 36 months demonstrated significant level and slope changes, and significant rate reductions at 12, 24 and 36 months when compared with the observed intervention trend for both primary outcomes.^{25 26} The counterfactual control modelled from −36 to −13 months of pre-intervention outcome data also demonstrated a significant slope change from a positive inclining slope pre-intervention to a negative declining slope during intervention. The rate reduction in COPD-related hospital admissions was of borderline significance at 12 months, reaching significance at 24 and 36 months. Lastly, when participants who died were removed from the models (N=328), the observed COPD-related hospital admission rate and ED visit rate remained significantly reduced in intervention period compared with the counterfactual control trend line at 12, 24 and 36 months (online supplemental tables 5E and 6E).

DISCUSSION

After 3 years of progressively increasing acute HSU, Best Care COPD, a primary care-based IDM programme, was associated with a significant and progressive reduction in COPD-related hospitalisation and ED visits over a 3-year interval. The observed impact was immediate and trajectory changing, a significant positive outcome for the COPD population and for the health system. Similarly, all-cause hospitalisation, ED visits and bed days exhibited significant and progressive reductions. To our knowledge, this is the first real-world interrupted time

Table 2 Observed health service utilisation events over the 6-year observation window

	Pre-intervention			Intervention period		
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
	N=2451*	N=2451	N=2451	N=2451	N=2350	N=1740
COPD-related hospital admissions						
Participants with event	62 (2.5%)	93 (3.8%)	225 (9.2%)	154 (6.3%)	138 (5.9%)	98 (5.6%)
Number of events	78	116	283	205	179	119
Mean events/participant (SD)	0.03 (0.24)	0.05 (0.28)	0.12 (0.41)	0.08 (0.37)	0.07 (0.37)	0.06 (0.29)
Number of bed days	483	768	1924	1387	1201	847
Mean bed days/participant	0.20 (1.66)	0.31 (1.96)	0.78 (3.48)	0.57 (2.94)	0.49 (2.52)	0.44 (2.44)
COPD-related ED visits						
Participants with event	213 (8.7%)	295 (12.0%)	499 (20.4%)	380 (15.5%)	314 (13.4%)	205 (11.8%)
Number of events	339	460	809	697	527	305
Mean events/participant (SD)	0.14 (0.66)	0.19 (0.69)	0.33 (0.88)	0.28 (0.93)	0.22 (0.77)	0.16 (0.57)
All-cause hospital admissions						
Participants with event	311 (12.7%)	337 (13.7%)	520 (21.2%)	501 (20.4%)	426 (18.1%)	319 (18.3%)
Number of events	410	466	743	752	641	470
Mean events/participant (SD)	0.17 (0.50)	0.19 (0.56)	0.30 (0.71)	0.31 (0.72)	0.26 (0.70)	0.25 (0.66)
All-cause ED visits						
Participants with event	876 (35.7%)	979 (39.9%)	1206 (49.2%)	1112 (45.4%)	932 (39.7%)	664 (38.2%)
Number of events	2070	2332	2941	2862	2406	1499
Mean events/participant (SD)	0.84 (2.07)	0.95 (1.96)	1.20 (2.04)	1.17 (2.19)	1.02 (2.33)	0.86 (1.74)
All-cause mortality				101 (4.1%)	113 (4.8%)	114 (6.6%)

See online supplemental table 1E for ICD-10 codes used for COPD-related disease classifications.

*N refers to the number of participants in the cohort at the beginning of the observation year.

COPD, chronic obstructive pulmonary disease; ED, emergency department; ICD-10, International Classification of Diseases, 10th revision; T₀, initial visit.

series analysis evaluating the beneficial long-term impact of IDM at the health system level.

The existence of an exacerbating phenotype, the ‘frequent exacerbator’, is codified in the GOLD guidelines.^{130 31} Best Care COPD sought to identify high-risk, exacerbation-prone individuals with COPD, as such, 23% were in the highest GOLD risk category group E (GOLD 2023 reclassified GOLD C and D). We observed increasing rates of COPD-related hospitalisation and ED visits over the 3 years before patients entered the programme. The observed pre-intervention increase in acute HSU aligns with the natural history of COPD where an increase in the frequency and severity of exacerbation has been documented in large observational cohort studies.^{6–8 30 32 33}

A majority of patients receive their COPD care in primary care.³⁴ Recently, the efficacy of COPD IDM has been confirmed in a high-quality meta-analysis with 52 RCTs and 21 086 patients including IDM administered in primary care.¹³ Importantly, efficacy in RCTs cannot be assumed, *a priori*, to translate into effectiveness in real-world clinical care.^{19 35} The effectiveness at 12 months after IDM implementation in our real-world primary care clinical practice study is consistent with RCT efficacy data.¹³ In 4207 participants, from 15 RCTs, the authors found a difference in respiratory-related admissions between intervention and control of 89 hospital admissions per 1000 per year, with a median follow-up of 12 months. In our real-world primary care study, we observed a reduction of up to 84 hospital admissions per 1000 at 12 months (table 3). The relative reductions in hospitalisation and ED visits at 12 months in our study ranged up to 51% and 36%, respectively, vs 36% and 31% in the meta-analysis.

In parallel to the increase in COPD-related HSU, we also observed an increase in all-cause, ED visits and hospitalisation over the 3 years prior to the Best Care intervention. Disease comorbidity is common in patients who live with COPD and the general increase in acute HSU may be expected.¹⁰ In our COPD cohort, 84% had at least one comorbid disease and 38% had more than two (table 1). Gershon and colleagues observed that people with COPD had rates of all-cause hospital and ED visits that were substantially higher than a matched population without COPD.³⁶ We observed a marked reduction in all-cause hospitalisation and ED visits at 12, 24 and 36 months. Again, our observations aligned with the meta-analysis by Poot and colleagues. At 12 months, we demonstrated a relative reduction in all-cause hospitalisation of up to 22% vs a 25% reduction reported by Poot and colleagues.¹³ Although COPD IDM is targeted at management of COPD, the health system impact extends to all-cause HSU.

CV disease is one of the most prevalent comorbidities for individuals with COPD and contributed to all-cause hospitalisation in this study.^{10 37 38} Post-intervention, significant reductions in CV-related admissions were observed at 12, 24 and 36 months. Although this exploratory analysis requires confirmation, it raises interesting questions. For example, if a COPD IDM programme impacts CV outcomes, what is the mechanism, pharmacological, non-pharmacological or both? In the context of two large RCTs where the addition of inhaled corticosteroids generated a 0.8% and 1% reduction in all-cause mortality, a majority of which were CV-related deaths, it is interesting to consider that medication optimisation in COPD may have contributed to the reduction in all-cause and CV-related hospitalisation in our study.^{39 40}

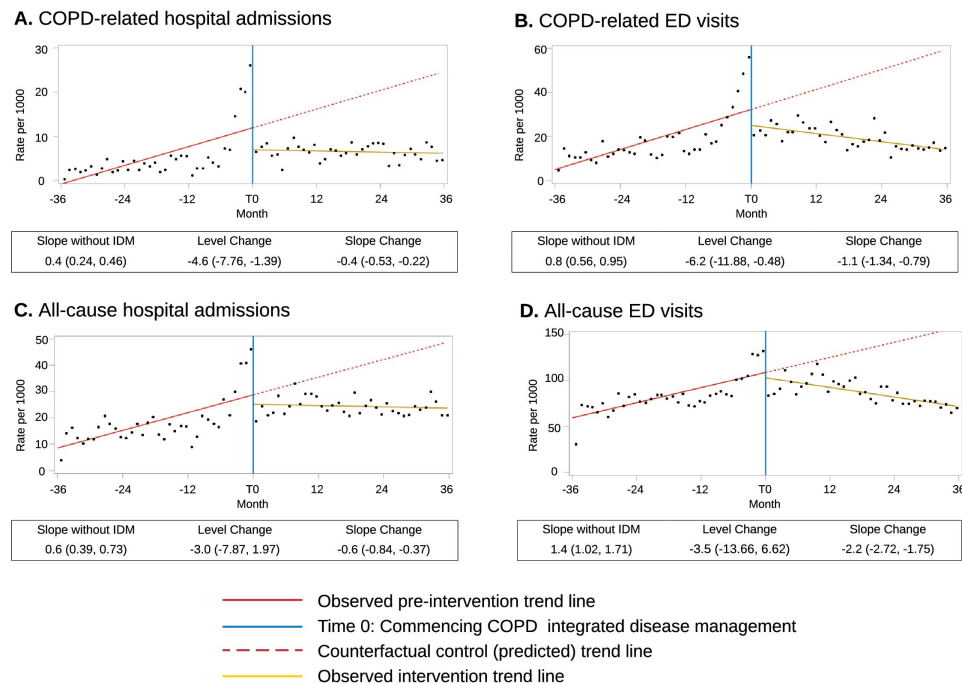


Figure 3 Time series graphs of health service events showing the observed pre-intervention monthly rate and trend line, the observed intervention monthly rate and trend line and the counterfactual control trend line for (A) COPD-related hospital admissions, (B) COPD-related ED visits, (C) all-cause hospital admissions, and (D) all-cause ED visits. Slope=the increase or decrease in event rate per 1000 individuals per month with (95% CI); level change=the increase or decrease in event rate per 1000 individuals from the observed pre-intervention trend line to the observed intervention trend line at time 0 with (95% CI); slope change=the difference between the slope without IDM and the slope with IDM in event rate per 1000 individuals per month (95% CI). Counterfactual control modelled from the observed pre-intervention trend line. COPD, chronic obstructive pulmonary disease; ED, emergency department; IDM, integrated disease management.

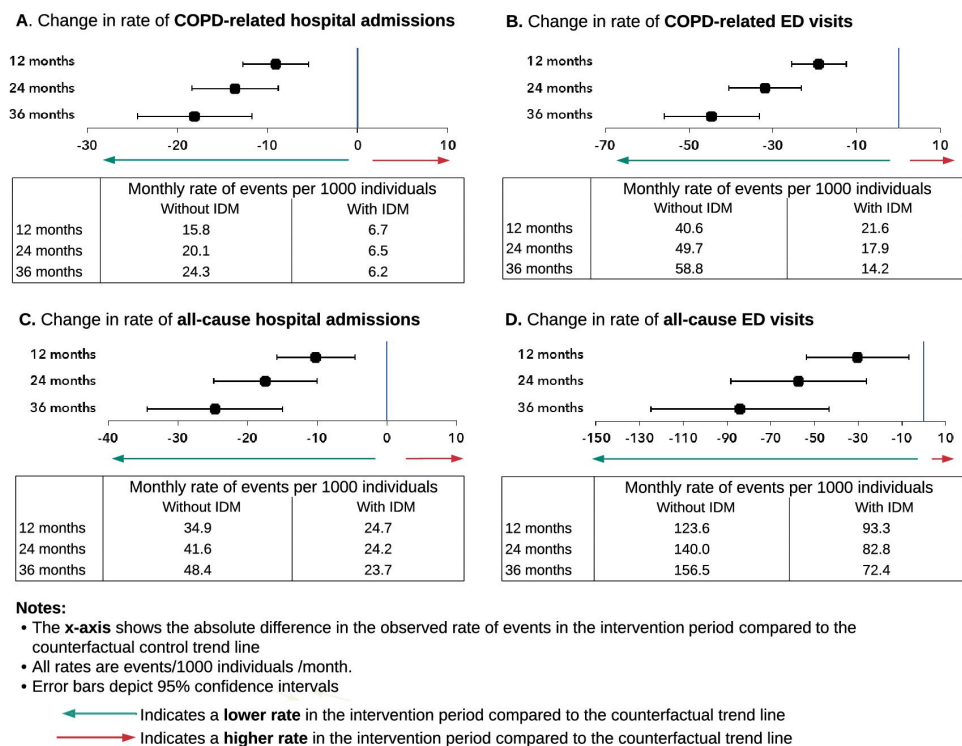


Figure 4 Change in the monthly rate of health service events comparing observed intervention trend line with the counterfactual control trend line at 12, 24 and 36 months for (A) COPD-related hospital admissions, (B) COPD-related ED visits, (C) all-cause hospital admissions, and (D) all-cause ED visits. COPD, chronic obstructive pulmonary disease; ED, emergency department; IDM, integrated disease management.

Table 3 Estimated health service utilisation events avoided, per 1000 patients, with each year of integrated disease management (IDM) if the 3-year pre-intervention trend had continued along the same trajectory without intervention

	In year 1 of IDM		In year 2 of IDM		In year 3 of IDM	
	Events avoided/1000 participants/year*	Relative reduction in event rate/1000/year†	Events avoided/1000 participants/year*	Relative reduction in event rate/1000/year†	Events avoided/1000 participants/year*	Relative reduction in event rate/1000/year†
COPD-related hospital admissions	61–84	43–51%	64–138	45–64%	67–192	47–72%
COPD-related ED visits	107–157	28–36%	152–311	39–57%	196–465	51–71%
All-cause hospital admissions	45–82	13–22%	51–169	15–37%	57–256	17–47%
All-cause ED visits	126–217	10–16%	251–539	19–34%	376–861	29–48%

*Lower range: the rate of events per 1000 participants in a year if the pre-intervention rate had remained constant at T_0 minus the rate of events per 1000 participants under the observed trend during the intervention period. Upper range: the rate of events per 1000 participants in a year if the pre-intervention trend had continued along the same trajectory minus the rate of events per 1000 participants under the observed trend during the intervention period.

†Lower range: the events avoided per 1000 participants in a year as a percentage of the rate of events per 1000 participants in a year if the pre-intervention rate had remained constant from T_0 . Upper range: the events avoided per 1000 participants in a year as a percentage of the rate of events per 1000 participants in a year if the pre-intervention trend had continued along the same trajectory.

COPD, chronic obstructive pulmonary disease; ED, emergency department.

To our knowledge, there were no other chronic disease management programmes introduced in Ontario that were consistently sustained in our study population. In addition, the 6-year chronological snapshot for each individual participant was centred around T_0 which includes dates from 2011 to 2019 mitigating any impact that a programme running concurrently would have. The quasi-experiment design used in this study is well suited to population health studies but inherent in the design is the lack of a physical control group. Rather, this methodology uses 36-month outcome measurements to establish a robust 3-year pre-intervention trend that when extended into the future, serves as a counterfactual control group.⁴¹ We observed a large increase in events in the year prior to commencing IDM, and while an increase in the frequency of COPD exacerbation is expected, we considered that referral bias may have contributed to this observation.^{6–8 30 32 33} To address this limitation, we conducted two sensitivity analyses with more conservative counterfactual controls and in each, confirmed our primary outcomes. Further to this limitation, we used both a clinical and objectively confirmed COPD diagnosis for study inclusion, introducing a potential for disease misclassification. Since the primary outcome data emanate from the provincial health system and not from the primary care provider, the reported outcomes are not affected. The potential impact of misclassification will be a dilution of the reported health service rates. The inclusion of participants with a clinical diagnosis of COPD may strengthen external validity of the study.

While we acknowledge that a single interrupted time series analysis does not prove causation, there are several factors that support an inference of causation. In the case of an RCT, random allocation to group excludes the effect of confounding. In the single interrupted time series design, the control group has the same features as the intervention group (they are the same); thus, similar to the RCT, individual-level confounding is minimised. The interrupted time series design can be impacted by rapidly changing time-varying confounders such as seasonality; however, centring our data around the initial visit mitigated this effect.⁴¹ There is striking temporality in that the effect of IDM on COPD-related HSU in this study is immediate and sustained. Finally, our findings are aligned with experimental evidence from RCTs.⁴² In this study, we specifically sought to identify participants in primary care at risk of future exacerbation; thus, our study population was enriched by high-risk exacerbation-prone patients. We acknowledge therefore that the reported

outcomes may not be generalisable across the full spectrum of disease severity in an unselected primary care population.

To our knowledge, this is the first health system study to associate a primary care-based COPD IDM programme with reduced hospitalisation and ED visits in a real-world setting. Further studies with other populations and in other jurisdictions are required to confirm the broader applicability of these findings. Future studies to identify the impact of COPD IDM in different patient subgroups considering disease severity, socioeconomic status, geography and comorbidity are needed. The health system impact of primary care-based IDM on other chronic diseases also deserves investigation.

CONCLUSION

In this large community-based, COPD population study including over 13 000 person-years of follow-up, we identified substantial and sustained long-term reductions in acute health services use after implementing primary care-based COPD IDM. Primary care IDM is an effective solution with the potential to improve international health systems where low guideline concordance and high rates of acute HSU are common. Our findings highlight how IDM, which implements a multiplicity of guideline-based care components, can deliver proactive upstream health system-level impacts.

Author affiliations

¹Schulich School of Medicine & Dentistry, Western University, London, Ontario, Canada

²Lawson Health Research Institute, London, Ontario, Canada

³Asthma Research Group Windsor-Essex County Inc, Windsor, Ontario, Canada

⁴Department of Public Health Sciences, Queen's University, Kingston, Ontario, Canada

⁵Hôtel-Dieu Grace Healthcare, Windsor, Ontario, Canada

⁶Child Health Evaluative Sciences, The Hospital for Sick Children, Toronto, Ontario, Canada

⁷Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada

⁸Telfer School of Management, University of Ottawa, Ottawa, Ontario, Canada

⁹Faculty of Health Sciences, Western University, London, Ontario, Canada

¹⁰Amherstburg Family Health Team, Amherstburg, Ontario, Canada

Acknowledgements The authors would like to acknowledge all patients enrolled in the Best Care COPD Programme, participating primary care providers, and all members of the Best Care team for their hard work and dedication. Parts of this report are based on Ontario Registrar General (ORG) information on deaths, the original source of which is ServiceOntario. The views expressed therein are those of the author and do not necessarily reflect those of ORG or the Ministry of Public and Business Service Delivery.

Contributors Concept and design—CL, AH, MF, ZL and TT. Acquisition and analysis—CL, AH, VR, MF, ZL, KZ, ET and TT. Drafting of the manuscript—CL and AH. All authors (AH, CF, MF, CL, ZL, TO'C, TT, VR, AS, SS, ET, KZ) contributed and made substantial contribution to the writing and critical review of the paper and gave final approval of the manuscript to be published. The lead author (CL) affirms that the manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned (and, if relevant, registered) have been explained. As the guarantor (CL) accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. Ethics approval including a waiver for informed consent was obtained from the Western University Health Sciences Research Ethics Board, Ontario, Canada (reference number: 114259) and from SickKids Research Ethics Board, Ontario, Canada (reference number: 1000075772). Consent was not obtained, as this was a retrospective administrative dataset evaluation of the Best Care COPD Programme.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. We are not able to provide a minimal dataset for this study due to privacy, legal, prescribed entity designations and ethical restrictions. All data used in this study are securely housed at ICES, Ontario, Canada in coded form and are subject to their privacy, legal, prescribed entity designations and ethical governance, and are available at www.ices.on.ca/Data-and-Privacy/Privacy-at-ICES (email: privacy@ices.on.ca). While legal data sharing agreements between ICES and data providers (eg, healthcare organisations and government) prohibit ICES from making the dataset publicly available, access may be granted to those who meet prespecified criteria for confidential access; available at <http://www.ices.on.ca/DAS> (email: das@ices.on.ca).

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iD

Anna Hussey <http://orcid.org/0000-0002-9940-638X>

REFERENCES

- Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management and prevention of chronic obstructive lung disease. 2023. Available: <https://goldcopd.org/2023-gold-report-2/> [Accessed 20 Sep 2023].
- Criner GJ, Bourbeau J, Diekemper RL, et al. Prevention of acute exacerbations of chronic obstructive pulmonary disease: American College of Chest Physicians and Canadian Thoracic Society guideline. *Chest* 2015;147:894–942.
- Safiri S, Carson-Chahhoud K, Noori M, et al. Burden of chronic obstructive pulmonary disease and its attributable risk factors in 204 countries and territories, 1990–2019: results from the Global Burden of Disease Study 2019. *BMJ* 2022;378:e069679.
- Kirsch F, Schramm A, Schwarzkopf L, et al. Direct and indirect costs of COPD progression and its comorbidities in a structured disease management program: results from the LQ-DMP study. *Respir Res* 2019;20:215.
- Rehman AU, Hassali MAA, Muhammad SA, et al. The economic burden of chronic obstructive pulmonary disease (COPD) in Europe: results from a systematic review of the literature. *Eur J Health Econ* 2020;21:181–94.
- Suissa S, Dell'Aniello S, Ernst P. Long-term natural history of chronic obstructive pulmonary disease: severe exacerbations and mortality. *Thorax* 2012;67:957–63.
- Sánta B, Tomisa G, Horváth A, et al. Severe exacerbations and mortality in COPD patients: a retrospective analysis of the database of the Hungarian national health insurance fund. *Pulmonology* 2023;29:284–91.
- Rothnie KJ, Müllerová H, Smeeth L, et al. Natural history of chronic obstructive pulmonary disease exacerbations in a general practice-based population with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2018;198:464–71.
- Mannino DM, Higuichi K, Yu T-C, et al. Economic burden of COPD in the presence of comorbidities. *Chest* 2015;148:138–50.
- Divo M, Cote C, de Torres JP, et al. Comorbidities and risk of mortality in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2012;186:155–61.
- Gershon AS, Guan J, Victor JC, et al. Quantifying health services use for chronic obstructive pulmonary disease. *Am J Respir Crit Care Med* 2013;187:596–601.
- Gershon A, Thiruchelvam D, Moineddin R, et al. Forecasting hospitalization and emergency department visit rates for chronic obstructive pulmonary disease. A time-series analysis. *Ann Am Thorac Soc* 2017;14:867–73.
- Poot CC, Meijer E, Kruis AL, et al. Integrated disease management interventions for patients with chronic obstructive pulmonary disease. *Cochrane Database Syst Rev* 2021;9:CD009437.
- Alison JA, McKeough ZJ, Johnston K, et al. Australian and New Zealand pulmonary rehabilitation guidelines. *Respirology* 2017;22:800–19.
- Spencer LM, McKeough ZJ. Maintaining the benefits following pulmonary rehabilitation: achievable or not? *Respirology* 2019;24:909–15.
- Craig P, Dieppe P, Macintyre S, et al. Developing and evaluating complex interventions: the new Medical Research Council guidance. *BMJ* 2008;337:a1655.
- Ferrone M, Masciantonio MG, Malus N, et al. The impact of integrated disease management in high-risk COPD patients in primary care. *NPJ Prim Care Respir Med* 2019;29:8.
- Scarffe AD, Licskai CJ, Ferrone M, et al. Cost-effectiveness of integrated disease management for high risk, exacerbation prone, patients with chronic obstructive pulmonary disease in a primary care setting. *Cost Eff Resour Alloc* 2022;20:39.
- Adams EJ, van Doornewaard A, Ma Y, et al. Estimating the health and economic impact of improved management in prevalent chronic obstructive pulmonary disease populations in England, Germany, Canada, and Japan: a modelling study. *Int J Chron Obstruct Pulmon Dis* 2023;18:2127–46.
- Hussey AJ, Wing K, Ferrone M, et al. Integrated disease management for chronic obstructive pulmonary disease in primary care, from the controlled trial to clinical program: a cohort study. *Int J Chron Obstruct Pulmon Dis* 2021;16:3449–64.
- Sibbald SL, Misra V, daSilva M, et al. A framework to support the progressive implementation of integrated team-based care for the management of COPD: a collective case study. *BMC Health Serv Res* 2022;22:420.
- Paciocco S, Kothari A, Licskai CJ, et al. Evaluating the implementation of a chronic obstructive pulmonary disease management program using the consolidated framework for implementation research: a case study. *BMC Health Serv Res* 2021;21:717.
- Sibbald SL, Paciocco S, Huizhu Chen L, et al. A peer-to-peer approach to implementation of a chronic disease management program. *JRIPE* 2023;12.
- Ontario Health. Quality standards: chronic obstructive pulmonary disease, care in the community for adults (2023 update). n.d. Available: <https://www.hqontario.ca/Portals/0/documents/evidence/quality-standards/qs-chronic-obstructive-pulmonary-disease-quality-standard-2023-en.pdf>
- Hawton K, Bergen H, Simkin S, et al. Long term effect of reduced pack sizes of paracetamol on poisoning deaths and liver transplant activity in England and Wales: interrupted time series analyses. *BMJ* 2013;346:f403.
- Ansari F, Gray K, Nathwani D, et al. Outcomes of an intervention to improve hospital antibiotic prescribing: interrupted time series with segmented regression analysis. *J Antimicrob Chemother* 2003;52:842–8.
- Sibbald SL, Law B, Van Asseldonk R, et al. Using visual methods to capture patient perspectives in interprofessional team-based care for chronic disease management. *JRIPE* 2022;12.
- Law B, Chhatwal PK, Licskai C, et al. Patient engagement in Interprofessional team-based chronic disease management: a qualitative description of a Canadian program. *Patient Educ Couns* 2023;114:107836.
- Hodson M, Roberts CM, Andrew S, et al. Development and first validation of a patient-reported experience measure in chronic obstructive pulmonary disease (PREM-C9). *Thorax* 2019;74:600–3.
- Hurst JR, Vestbo J, Anzueto A, et al. Susceptibility to exacerbation in chronic obstructive pulmonary disease. *N Engl J Med* 2010;363:1128–38.
- Pavord ID, Jones PW, Burgel P-R, et al. Exacerbations of COPD. *Int J Chron Obstruct Pulmon Dis* 2016;11 Spec Iss:21–30.
- Whittaker H, Rubino A, Müllerová H, et al. Frequency and severity of exacerbations of COPD associated with future risk of exacerbations and mortality: a UK routine health care data study. *Int J Chron Obstruct Pulmon Dis* 2022;17:427–37.
- Hurst JR, Han MK, Singh B, et al. Prognostic risk factors for moderate-to-severe exacerbations in patients with chronic obstructive pulmonary disease: a systematic literature review. *Respir Res* 2022;23:1–23.
- Cho EE, Mecredy GC, Wong HH, et al. Which physicians are taking care of people with COPD? *Chest* 2019;155:771–7.
- Çolak Y, Nordestgaard BG, Lange P, et al. Prognosis of patients with chronic obstructive pulmonary disease not eligible for major clinical trials. *Am J Respir Crit Care Med* 2022;206:271–80.

- 36 Gershon AS, Mecredy GC, Guan J, *et al.* Quantifying Comorbidity in individuals with COPD: a population study. *Eur Respir J* 2015;45:51–9.
- 37 Chen W, Thomas J, Sadatsafavi M, *et al.* Risk of cardiovascular comorbidity in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. *Lancet Respir Med* 2015;3:631–9.
- 38 Ellingsen J, Johansson G, Larsson K, *et al.* Impact of comorbidities and commonly used drugs on mortality in COPD – real-world data from a primary care setting. *Int J Chron Obstruct Pulmon Dis* 2020;15:235–45.
- 39 Lipson DA, Barnhart F, Brealey N, *et al.* Once-daily single-inhaler triple versus dual therapy in patients with COPD. *N Engl J Med* 2018;378:1671–80.
- 40 Rabe KF, Martinez FJ, Ferguson GT, *et al.* Triple inhaled therapy at two glucocorticoid doses in moderate-to-very-severe COPD. *N Engl J Med* 2020;383:35–48.
- 41 Bernal JL, Cummins S, Gasparrini A. Interrupted time series regression for the evaluation of public health interventions: a tutorial. *Int J Epidemiol* 2017;46:348–55.
- 42 HILL AB. The environment and disease: association or causation? *Proc R Soc Med* 1965;58:295–300.