



Effect of a Multimorbidity Intervention on Health Care Utilization and Costs in Ontario: RCT and Propensity-matched Analyses

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Keywords:	Family medicine, general practice, primary care, Health services research
More Detailed Keywords:	Multimorbidity, Health service utilization, patient-centred, propensity scores
Abstract:	<p>Background: Patients with multimorbidity require coordinated and patient-centred care. The Telemedicine IMPACT Plus (TIP) program provides such care for complex patients in Toronto, Ontario. We conducted an RCT and compared health care utilization and costs one year following the intervention for the intervention group and two control groups (RCT controls and propensity-matched controls).</p> <p>Methods: Data for 82 RCT intervention and 74 RCT control participants were linked with health administrative data. We created a second control group using health administrative data-derived propensity scores to match (1:5) intervention participants with comparator patients. We evaluated five outcomes: Acute hospitalizations; Emergency department (ED) visits; Costs; 30-day hospital readmissions; and 7-day follow-up with family physician (FP) after hospital discharge using generalized estimating equations for the RCT controls and difference-in-differences for the propensity-matched controls.</p> <p>Results: There were no statistically significant differences between the</p>

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	<p>intervention group and either of the two control groups on any of the five outcomes. Absolute changes were small however, a higher percentage of intervention participants received follow-up from their family physicians compared either to RCT controls (53.13% versus 21.43%; relative difference 2.48 90.98-6.29) or propensity-matched controls (49.94% versus 28.21%; difference in differences 1.81 (0.99-3.30).</p> <p>Interpretation: Despite a complex patient-centred intervention, there was no statistically significant improvement in health care utilization or cost for patients who received the intervention. Future research requires larger sample sizes and should include outcomes important to patients and the health care system, as well as longer follow-up periods.</p> <p>Trial Registration: This study's Ontario ClinicalTrials.gov registration number is 104191.</p>

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STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) Statement*

Section/topic	Item No	Recommendation	Page number
Title and abstract	<input type="checkbox"/> 1	Indicate the use of propensity analysis with a commonly used term in the title or the abstract	Title page
	<input type="checkbox"/> 2	Provide in the abstract an informative and balanced summary of what was done and what was found	Abstract
Introduction			
Background/rationale	<input type="checkbox"/> 3	Explain the scientific background and rationale for the investigation being reported	1
Objectives	<input type="checkbox"/> 4	State specific objectives, including any prespecified hypotheses	1
Methods			
Setting	<input type="checkbox"/> 5	Describe the setting, locations, and relevant dates, including periods of recruitment, treatment, follow-up, and data collection	1, 2
Patient selection	<input type="checkbox"/> 6	Give the eligibility criteria, and the sources and methods of subject ascertainment and selection	3-4
Variables	<input type="checkbox"/> 7	Clearly define all outcomes, treatments, predictors. Give diagnostic criteria, if applicable	2-4
Data sources/ measurement	<input type="checkbox"/> 8	For each variable of interest, give sources of data and details of methods of assessment (measurement)	2, 3 (appendix 1; appendix 2)
Bias	<input type="checkbox"/> 9	Describe how propensity score analysis was used to address bias	2
	<input type="checkbox"/> 10	Describe any other methods to address potential sources of bias, e.g. sensitivity analysis	3
Sample size	<input type="checkbox"/> 11	Explain how the study size was arrived at	3
Statistical analyses	<input type="checkbox"/> 12	Describe all the analytic methods, including the propensity score methods, e.g. matching, weighting, stratification, or covariate adjustment using propensity score	3 (RCT), 4-5 (Propensity)
	<input type="checkbox"/> 13	Indicate the model used to estimate propensity score, e.g. logistic model, boosting (meta-classifiers), decision trees	4
	<input type="checkbox"/> 14	State the variables included in the propensity score model	4
	<input type="checkbox"/> 15	Explain the variable selection procedure for propensity score model	4
	<input type="checkbox"/> 16	For propensity score matching:	
	<input type="checkbox"/> 16.1	Explicitly state the matching algorithm and distance metric	4

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<input type="checkbox"/>	16.2	Indicate matching ratio (1:m matching)	4
<input type="checkbox"/>	16.3	Indicate whether sampling with or without replacement was used	4
<input type="checkbox"/>	16.4	Describe the statistical methods for the analysis of matched data	4
<input type="checkbox"/>	16.5	Describe methods for assessing the comparability of baseline characteristics in the matched groups	4
<input type="checkbox"/>	17	For propensity score weighting, describe methods for assessing the comparability of baseline characteristics in the weighted groups	N/A
	18	For propensity score stratification:	N/A
<input type="checkbox"/>	18.1	Give the number of strata	
<input type="checkbox"/>	18.2	Describe methods for assessing the comparability of baseline characteristics in each stratum	
<input type="checkbox"/>	19	Explain how assumption of propensity score analysis was examined	4
<input type="checkbox"/>	20	Explain how missing data were addressed, including missing data in propensity score estimation	3
<input type="checkbox"/>	21	If applicable, describe any methods used to examine subgroups and interactions	N/A
<input type="checkbox"/>	22	Describe any sensitivity analyses	3
<input type="checkbox"/>	23	Indicate the software used for analysis	2
<input type="checkbox"/>	24	If applicable, report the package used to create matched sample, e.g. GMATCH macro in SAS, MatchIt package®, Optmatch package ®	2

Results

Participants	25	Report numbers of participants at each stage of study:	
	<input type="checkbox"/> 25.1	sample size of patients potentially eligible	Figure 1
	<input type="checkbox"/> 25.2	sample size of patients confirmed eligible and included	Figure 1
	<input type="checkbox"/> 25.3	sample size of patients analyzed	Figure 1
	<input type="checkbox"/> 25.4	for propensity score matching, sample size for each treatment group before and after matching	Figure 1
	<input type="checkbox"/> 26	Explain reasons for exclusion at each stage	Figure 1
	<input type="checkbox"/> 27	Consider use of a flow diagram	Figure 1
Patient characteristics	<input type="checkbox"/> 28	Describe the distribution of baseline characteristics for each group before propensity score analysis	Table 3
	29	For propensity score matching, weighting, or stratification:	
	<input type="checkbox"/> 29.1	Describe the distribution of baseline characteristics in the matched/weighted groups or in each stratum	Table 3

	<input type="checkbox"/>	29.2	Describe the results of the comparability of baseline characteristics, whether there are still systematic differences between treatment groups	Table 3 and 6
	<input type="checkbox"/>	30	Indicate number of patients with missing data for each variable of interest, especially the variables used in propensity score model	Table 1
Outcome data	<input type="checkbox"/>	31	Report outcomes of each treatment group	4-5/ Table 2 (RCT)
Main results	<input type="checkbox"/>	32	Give propensity score analysis estimates and their precision, e.g. 95% confidence interval	5/ Table 4 (Propensity)
	<input type="checkbox"/>	33	If applicable, give unadjusted estimates and/or adjusted estimates and their precision, e.g. 95% confidence interval. Make clear which additional factors were adjusted for	N/A
Other analyses	<input type="checkbox"/>	34	Report other analyses done, e.g. analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion				
Key results	<input type="checkbox"/>	35	Summarize key results with reference to study objectives	5-6
Limitations	<input type="checkbox"/>	36	Discuss limitations of the study, taking into account sources of potential bias or imprecision	6
	<input type="checkbox"/>	37	Discuss both direction and magnitude of any potential bias	6
Interpretation	<input type="checkbox"/>	38	Discuss whether imbalance of baseline characteristics still exists, and give a cautious interpretation	N/A
	<input type="checkbox"/>	39	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6
Generalizability	<input type="checkbox"/>	40	For propensity score matching, discuss the possibility and potential influence of incomplete matching, especially the studies in which the matched sample size is less than 50%	N/A
Other information				
Funding	<input type="checkbox"/>	41	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Online submission

* von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61(4):344-9.

This guideline can be downloaded at: <https://sites.duke.edu/xiaofeiwang/files/2016/12/Supplementary-Table-6.pdf>

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Effect of a Multimorbidity Intervention on Health Care Utilization and Costs in Ontario: RCT and Propensity-matched Analyses

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Data Sharing Statement

The data set from this study is held securely in coded form at ICES. While data sharing agreements prohibit ICES from making the data set publicly available, access may be granted to those who meet prespecified criteria for confidential access, available at <https://www.ices.on.ca/DAS>. The full data set creation plan and underlying analytic code are available from the authors on request, understanding that the computer programs may rely on coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

Introduction

Multimorbidity is common, occurs increasingly at younger ages^{1,2} and is associated with a high burden on patients and the health care system.³ Care for patients with multimorbidity must consider the incremental challenges that multiple chronic conditions confers upon patients over and above the burden conferred by each individual condition.^{2,3} As such, patients with multimorbidity require care coordinated by teams of providers and care that attends to them as whole persons, not as a sum of their diseases.³⁻⁵

With these values of coordinated team-based care and patient-centred care as pillars, *Patient-centred Innovations for Persons with Multimorbidity (PACE in MM)* conducted two randomized controlled trials (RCTs) of primary care delivery for persons with multimorbidity, one in Quebec and one in Ontario.⁶ Details of the interventions including randomization⁶ and the effects of these interventions on patient-reported health outcomes^{7,9} are reported elsewhere.

The Ontario intervention took place in Toronto from 2016 to 2019. Nine team-based family practices, along with solo practices and emergency departments affiliated with those teams, provided care for complex patients with high health care utilization through Telemedicine IMPACT Plus (TIP), hereafter referred to as the intervention.⁸ The intervention consisted of a meeting between the patient and nurse where the patient's goals for care were elaborated and a subsequent case conference of approximately six providers relevant to the patient's needs, including a family physician known to the patient⁹. The target population was patients 18 to 80 years old with three or more chronic conditions.

This paper reports the effect on health services outcomes for patients enrolled in the Ontario arm of PACE in MM RCT.⁹ The first objective was to compare health care utilization and costs between intervention and control patients before and after the intervention. Anticipating a small sample size for a community-based complex intervention, the decision was made a priori⁷ to include a second objective where health care utilization and costs for intervention patients were examined relative to propensity-matched controls derived from health administrative (HA) data.

Methods

Data Sources

The data source for participant information for the PACE in MM Ontario RCT study was gathered from patient questionnaires completed through a telephone interview by a research assistant (RA) upon patient enrolment in the study. The RA was blinded to the participants' RCT assignment during interviews. Questionnaire data were transferred from paper, then verified by another RA, and stored in the study database. Variables relevant to the HA analysis were stored in the PACE in MM Ontario RCT study database (hereafter called PACE Database). Each participant was assigned an index date.

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In January 2020, the PACE Database (including index date, assignment (intervention or control), Ontario Health Insurance Plan (OHIP) number, age, sex, education, household income, marital status, employment and a list of patients’ chronic conditions) was transferred to ICES (Toronto, ON). ICES is an independent, non-profit research institute whose legal status under Ontario’s health information privacy law allows it to collect and analyze health care and demographic data, without consent, for health system evaluation and improvement. Data from the PACE Database and ICES HA databases were linked using unique encoded identifiers (derived from OHIP numbers) and analyzed at ICES. Appendix 1 describes the HA datasets used in analyses.

Overall Methods and Outcome Measures

We conducted two analyses. The first analysis compared intervention participants to RCT control patients (hereafter called RCT analysis). The second compared intervention participants to propensity-matched controls identified in HA data (hereafter called propensity-matched analysis). A priori, we expected the sample size for the RCT to be modest and therefore included a 5:1 propensity-matched analysis to increase power.⁶ This process created an analytical sample in which measured confounding factors were balanced between intervention arms. Below, the two analyses are described separately. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary, NC).

For both analyses, five outcomes were obtained from HA data for one year post-index date: 1. Acute hospitalizations; 2. Emergency department (ED) visits one year; 3. Costs (total); 4. 30-day hospital readmissions; and 5. 7-day follow-up with family physician (FP) after hospital discharge. Appendix 2 provides definitions for each outcome, including data sources used. Measures were chosen a priori to demonstrate important markers for PACE in MM success.⁶ Minor adjustments from protocol were made to some outcome definitions to align with measures available in HA data. Each outcome was measured for one year before the index date assigned to the patient and for one year after.

RCT Analysis

Sample

There were 86 intervention participants and 77 control participants.⁹ Participants were included if they were successfully linked to HA databases.

Covariates

Covariates were obtained from the PACE Database: age, sex, education, household income, marital status, employment and a list of the patients’ chronic conditions; a variable was created for number of chronic conditions. Covariates were used to describe and compare intervention and control groups.

Statistical Analysis

Differences in health care utilization over one year before and after index dates for PACE intervention group versus control group were determined using univariate regression with Generalized Estimating Equation (GEE) including a single covariate for RCT assignment (intervention or control). People were followed for one year post-index date; if a person died with less than one year of follow-up, this was accounted for through a person-time offset. A sensitivity analysis was done without using an offset. We estimated acute hospitalizations and ED visits using a negative binomial distribution with log-person-time offset; costs using a gamma distribution with log link function; 30-day hospital readmissions using a Poisson distribution with offset for number of index discharges in period of interest; and 7-day follow-up with FP using a Poisson distribution with offset for the number of index discharges in the period of interest.

Propensity-matched Analysis

Sample and Assignment of Index Dates

Individuals from the PACE intervention group were included in the study if they were successfully linked to HA databases. The index date used for intervention participants was date they received the intervention.

To create a pool of eligible comparators, we assigned all Ontarians in the Registered Persons Database a “pseudo-index date”. This date was based on the quarterly distribution of all index dates for only the intervention participants in the PACE database. From this pool, we excluded persons that did not have a physician encounter recorded OHIP 1 year prior to their pseudo-index date, were in hospital at pseudo-index date, were enrolled in Family Health Teams that participated in PACE in MM, were a rural resident or resided outside of the forward sortation areas (FSA; i.e., first 3 digits of postal code) of PACE participants, were missing income or rurality data, were a resident of a long-term care facility prior to pseudo-index or died within 1-year of pseudo-index (Figure 1).

Covariates

For intervention participants and for the comparator pool population (from which we drew the propensity-matched controls), we defined covariates – at index or pseudo-index date respectively – including age, sex, rurality (defined using the Rurality Index of Ontario¹⁴) and neighbourhood level income quintile. The history of 17 conditions were defined based on retrospective data from ICES databases as described in Appendix 3. The 17 conditions represent a subset of the most substantial conditions from a population perspective; these have been used extensively for multimorbidity research in Ontario.^{1,15–21} Additionally, we identified the number of urgent hospital admissions (DAD), emergency department visits (NACRS-ED), visits to FPs and specialist (OHIP) and total costs incurred across the healthcare system. These utilization variables were derived for the 1 year prior to index/pseudo-index as well as quarterly, leading up to index/pseudo-index.

Creating Propensity-matched Cohort

Persons in the comparator pool were matched five-to-one to persons in intervention group using propensity score methods without replacement. Propensity scores were derived from logistic regression modelling the probability of enrolment in the intervention as a function of variables relevant to patients with multimorbidity including age (modelled as a restricted cubic spline), sex, income quintile, rurality, history of 17 chronic conditions and quarterly counts of health care utilization, including urgent admissions, ED visits, visits to FPs and specialist and total costs. Utilization variables were transformed using a square-root function prior to modelling. We created a propensity-score-matched cohort using the nearest-neighbour greedy algorithm to match (up to) five comparators for every person in the intervention group.¹¹ Individuals were matched on sex (hard match), the logit of the propensity score (within 0.20 standard deviations [SD])[REF to be added], age (within 2 years), index/pseudo-index date (within 90 days) and total costs in the year prior to index/pseudo index (within 3 SD of the mean). To assess quality of the match, we used standardized differences [SDiff], weighted for many-to-one matching,¹² to compare baseline characteristics of the intervention group and comparators. A SDiff <0.10 is indicative of good balance between groups.¹³

Statistical Analysis

Differences in healthcare utilization in one year before and after index/pseudo-index for the PACE intervention group vs propensity-score-matched controls were determined using difference-in-differences estimation via GEEs. We estimated acute hospitalizations and ED visits using a negative binomial distribution and log-link function; costs were estimated using a gamma distribution and log-link function; and 30-day hospital readmissions and 7-day follow-up with FP (for hospitalized individuals) were estimated using a Poisson distribution and log-link function and an offset term for the log of total number of discharges per individual in the period. Each regression included a binary covariate for treatment group, a binary variable for time (pre- or post-index/pseudo-index) and the 2-way interaction between treatment and time. This latter term is the difference-in-differences estimator. An exchangeable correlation structure was used to account for correlation of repeated measured among individuals. The parallel trends of quarterly data were checked visually to ensure model assumptions were valid.

Ethics approval

Western University Health Sciences Research Ethics Board (106921) approved this study.

Results

RCT Analysis

A total of 82 of 86 participants from the PACE intervention group and 74 of 77 from the control group were successfully linked to HA data. There were no statistically significant differences in baseline characteristics between the groups (Table 1).

Table 2 reports the results of the GEE analysis comparing healthcare utilization and costs one year post-index date between intervention and control participants. There were no statistically significant differences for any of the outcomes of acute hospitalizations, ED visits, costs, 30-day hospital readmissions, and 7-day follow-up with FP.

Propensity-matched Analysis

A total of 82 participants from the PACE intervention group were successfully matched to HA data. The mean age at index for this group was 62 years (SD=14 years) and nearly two-thirds were women (65%). Persons from the lowest (29%) and highest (24%) area-based income quintiles were over-represented in the data. On average, persons in the PACE intervention group had a history of 5.4 (SD = 2.4) out of 17 conditions. The most common diagnoses were osteoarthritis (78% of participants), mood and anxiety disorders (78%), hypertension (61%) and cancer (59%). In the year prior to intervention, the PACE group had on average 9.5 FP visits (SD=9.9), 12.0 specialist visits (SD=15.3), 0.4 urgent hospital admissions (SD=0.9), 1.3 ED visits (SD=2.7) and incurred \$19,900 in healthcare costs (SD=\$27,900).

In propensity score matching, we matched the 82 intervention participants to 401 comparators. Seventy nine intervention participants were matched to five comparators; three were matched to only two comparators. Baseline covariates were balanced between matched groups (Table 3) with the exception of FP visits in the quarter prior to index/pseudo-index (SDiff=0.126), and specialist visits in the second quarter nearest to index/pseudo-index (SDiff=0.191, data not shown).

Table 4 reports the difference-in-differences estimation. Across the five outcomes, the DID estimators (i.e., interaction between intervention and period) were not statistically significant. This suggests that the change in utilization or costs before versus after index for the PACE intervention group was no different to that of the matched comparator group. Plots of crude quarterly data validated the parallel trend assumption required for DID analysis (not shown).

Interpretation

This paper reports the analysis of five hospital-based and cost outcomes for an RCT that provided patient-centred care for persons with multimorbidity. The RCT and the propensity-matched analyses found no statistically significant post-index differences in health care utilization or costs between intervention and control participants. For one outcome, 7-day follow-up with FP, intervention participants had twice (RCT analysis) and 1.8 times (propensity-matched analysis) the follow-up compared to control participants, but in both analyses, 95% confidence intervals included the null value.

The RCT findings from this HA analysis (RCT and propensity-matched comparisons) are congruent with findings on patient-reported outcomes at four months in the Ontario arm of the PACE in MM RCT.⁹ Results are also consistent with similar interventions. Another propensity-matched study of a community intervention called Health Links for persons with multiple

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chronic conditions in Ontario found no effect of on acute hospital admissions, readmissions or timely follow-up with primary care providers seven days after hospital discharge.¹⁹ This study included components similar to those in the PACE in MM RCT such as intensive care coordination, multidisciplinary care, and a patient-centred coordinated care plan outlining patient’s needs, goals, providers, treatments and appointments.^{19, p.1} Our results regarding the hospitalization outcome also correspond with Salisbury et al. who reported no difference in 15-month hospitalizations between intervention and control patients in a patient-centred RCT for management of multimorbidity.²² We identified other studies that tested complex interventions for people with multimorbidity but these did not have health care utilization outcomes.^{23–26}

Limitations

The main limitation for this analysis was the small sample size of 82 intervention participants and 74 controls. This may explain the lack of statistical significance found in the RCT analysis. We also conducted a propensity-matched analysis but found similar results. In the propensity-matched controls, it was not possible to match for every baseline characteristic collected in the questionnaires because these individual-level characteristics are not available in the HA data and so could not be included for the propensity matches. Therefore, we cannot rule out the possibility of unmeasured confounding due to the unavailability of variables such as lifestyle behaviours.

The majority of the control group in this RCT received usual care within a primary care team-based model and so usual care may have had similarities to the team-based care provided in the intervention which may impact health care utilization. Our outcomes were limited to hospital care and direct costs of health care services. The intervention may confer benefits aligned with outcomes that consider patient preferences such as improved function rather than those that affect health care utilization and costs. Our follow-up period of one year may not have been sufficiently long to see benefits from this complex intervention.

Conclusion

The results of this study add to the body of evidence that improving health for persons with multimorbidity continues to challenge us.^{7,9,22} Despite a complex patient-centred intervention, there was no statistically significant improvement in health care utilization or cost outcomes for patients who received the PACE in MM intervention. Future research requires larger sample sizes and should incorporate a wider range of outcomes important to patients and the health care system, as well as longer follow-up periods.

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Table 1. RCT Analysis: Baseline Characteristics

	Control n = 74	Intervention n = 82
	Mean (SD)	
Age (years)	62.8 (14.0)	62.1 (13.9)
Chronic conditions		
# of conditions per participant	6.01 (2.3)	6.18 (2.4)
	N (%)	
Gender		
Female	48 (64.9)	53 (64.6)
Male	26 (35.1)	29 (35.4)
Education level		
Incomplete secondary school	8 (10.8)	10 (12.2)
Completed secondary school	11 (14.9)	10 (12.2)
Some University or completed College	25 (33.8)	24 (29.3)
Completed bachelors degree	14 (18.9)	27 (32.9)
Completed graduate or professional degree	16 (21.6)	11 (13.4)
Household income in Cad\$		
Less than \$20 000	16 (21.6%)	20 (24.4%)
\$20,000-\$59,999	26 (35.1%)	17 (20.7%)
\$60,000 or more	23 (31.1%)	34 (41.5%)
Missing data	9 (12.2%)	11 (13.4%)
Marital status		
Married	36 (48.6%)	36 (43.9%)
Separated or Divorced	15 (20.3%)	17 (20.7%)
Widower	10 (13.5%)	8 (9.8%)
Never Married	13 (17.6%)	21 (25.6%)
Employment		
Employed	13 (17.6%)	16 (19.5%)
Unemployed	27 (36.5%)	29 (35.4%)
Retired from paid work	33 (44.6%)	37 (45.1%)
Missing	<=5 (1.4%)	0 (0.0%)

Table 2. RCT Analysis: Results for Outcomes One Year Post-index Date through Generalized Estimating Equations

Measure	Intervention Group (n=82) Mean estimate (CI)	Control Group (n=74) Mean estimate (CI)	Relative Difference* Mean estimate (CI)	p-value
Acute hospitalizations, #	0.49 (0.28-0.87)	0.34 (0.18-0.65)	1.43 (0.61-3.38)	0.413
Emergency department visits, #	0.94 (0.61-1.44)	0.93 (0.59-1.45)	1.02 (0.55-1.88)	0.963
Costs, \$	\$19,619 (15,368-25046)	\$15,424 (11,927-19,946)	1.27 (0.89-1.81)	0.184
30-day hospital readmissions, % [†]	28.13 (14.63-54.05)	25.00 (11.92-52.44)	1.13 (0.42-3.02)	0.815
7-day follow-up with family physician (%) [†]	53.13 (33.03-85.46)	21.43 (9.63-47.70)	2.48 (0.98-6.29)	0.056

*Relative difference is the ratio of the Intervention Group Mean estimate to the Control Group Mean estimate

[†]Sample size: Intervention = 16, Control = 17. Sample for this outcome only includes those participants who had hospital discharge in the period one year following their index date

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Table 3. Propensity-Matched Analysis: Comparison of Characteristics of Intervention Group to Comparator Group Before and After Matching

	Before Matching (Number (%)) [†]			After Matching (Number (%)) [†]		
Characteristics	Full control pool N=919027	Intervention Group N=82	Sdiff*	Matched controls N=401	Matched Intervention Group N=82	Sdiff*
Age at index date, mean ± SD	48.1 ± 16.6	62.0 ± 13.9	0.916	62.26 ± 13.85	62.05 ± 13.89	0.004
Female Sex	500,932 (54.5%)	53 (64.6%)	0.207	259 (64.6%)	53 (64.6%)	0.001
2008 Rurality Index for Ontario	0.5 ± 3.3	0.3 ± 1.6	0.093	0.27 ± 2.18	0.26 ± 1.56	0.006
Income quintile (area)						
Q1 (lowest)	250,292 (27.2%)	24 (29.3%)	0.045	130 (32.4%)	24 (29.3%)	0.068
Q2	202,409 (22.0%)	8 (9.8%)	0.340	29 (7.2%)	8 (9.8%)	0.091
Q3	181,609 (19.8%)	16 (19.5%)	0.006	72 (18.0%)	16 (19.5%)	0.040
Q4	115,786 (12.6%)	14 (17.1%)	0.126	70 (17.5%)	14 (17.1%)	0.010
Q5 (highest)	168,931 (18.4%)	20 (24.4%)	0.147	100 (24.9%)	20 (24.4%)	0.013
History of Co-morbidities						
AMI	10,540 (1.1%)	6 (7.3%)	0.310	22 (5.5%)	6 (7.3%)	0.080
Cardiac Arrhythmia	43,872 (4.8%)	19 (23.2%)	0.550	97 (24.2%)	19 (23.2%)	0.012
Asthma	136,220 (14.8%)	23 (28.0%)	0.327	110 (27.4%)	23 (28.0%)	0.011
Cancer	307,310 (33.4%)	48 (58.5%)	0.520	243 (60.6%)	48 (58.5%)	0.045
CHF	14,121 (1.5%)	16 (19.5%)	0.613	66 (16.5%)	16 (19.5%)	0.089
COPD	19,593 (2.1%)	14 (17.1%)	0.524	69 (17.2%)	14 (17.1%)	0.007
Chronic Coronary Syndrome	58,931 (6.4%)	24 (29.3%)	0.626	116 (28.9%)	24 (29.3%)	0.005
Dementia	7,957 (0.9%)	7 (8.5%)	0.369	26 (6.5%)	7 (8.5%)	0.084
Diabetes	121,533 (13.2%)	29 (35.4%)	0.534	147 (36.7%)	29 (35.4%)	0.033
Hypertension	243,883 (26.5%)	50 (61.0%)	0.740	258 (64.3%)	50 (61.0%)	0.071
Other Mental Health Conditions	199,619 (21.7%)	44 (53.7%)	0.698	229 (57.1%)	44 (53.7%)	0.066
Mood/Anxiety	422,683 (46.0%)	64 (78.0%)	0.700	313 (78.1%)	64 (78.0%)	0.006
Osteoarthritis	357,160 (38.9%)	64 (78.0%)	0.867	307 (76.6%)	64 (78.0%)	0.041
Osteoporosis	44,518 (4.8%)	9 (11.0%)	0.229	41 (10.2%)	9 (11.0%)	0.032
Renal Disease	21,327 (2.3%)	12 (14.6%)	0.453	57 (14.2%)	12 (14.6%)	0.000
Rheumatoid Arthritis	8,451 (0.9%)	<=5 (6.1%)	0.284	20 (5.0%)	<=5 (6.1%)	0.021
Stroke	13,061 (1.4%)	6 (7.3%)	0.291	26 (6.5%)	6 (7.3%)	0.009

Multimorbidity (2+/17 conditions)	532,801 (58.0%)	77 (93.9%)	0.926	384 (95.8%)	77 (93.9%)	0.089
Multimorbidity (3+/17 conditions)	343,401 (37.4%)	74 (90.2%)	1.318	348 (86.8%)	74 (90.2%)	0.100
Use of services, mean \pm SD						
Family Physician visits (year)	4.5 \pm 5.3	9.5 \pm 9.9	0.622	10.21 \pm 10.16	9.46 \pm 9.91	0.087
Specialist visits (year)	2.6 \pm 5.2	12.0 \pm 15.3	0.817	12.21 \pm 16.71	11.96 \pm 15.26	0.089
Acute admissions, urgent (year)	0.0 \pm 0.2	0.4 \pm 0.9	0.599	0.37 \pm 0.81	0.44 \pm 0.93	0.060
Acute admissions (year)	0.1 \pm 0.3	0.5 \pm 1.0	0.642	0.46 \pm 0.88	0.54 \pm 1.01	0.074
ED visits (year)	0.3 \pm 1.0	1.3 \pm 2.7	0.499	1.30 \pm 2.69	1.34 \pm 2.70	0.007
Total costs (year)	3,001.9 \pm 10,023.8	19,867.6 \pm 27,900.2	0.805	18,050.08 \pm 23,663.50	19,867.60 \pm 27,900.19	0.026

†Except where noted otherwise

* Standardized difference

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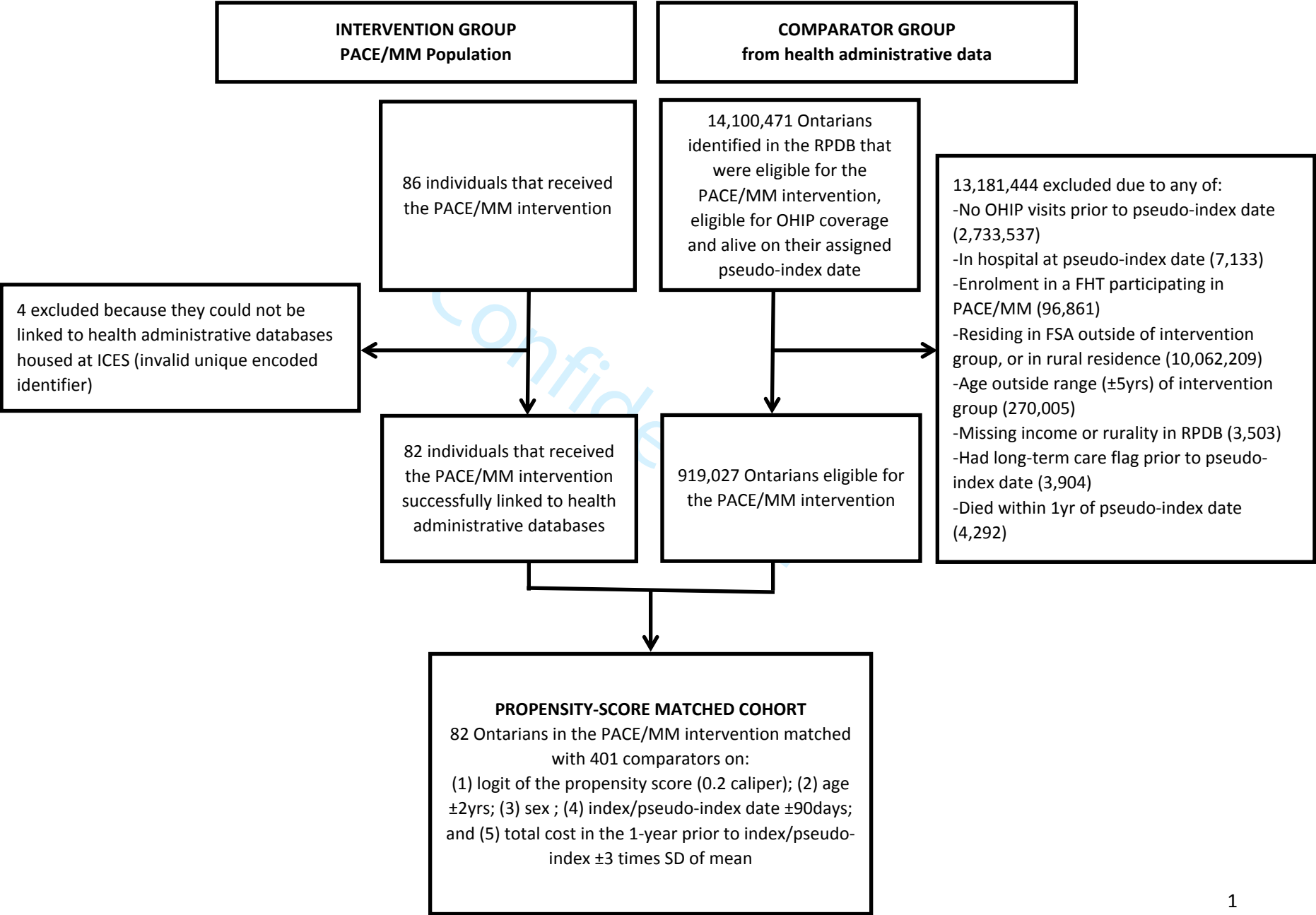
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Table 4. Propensity-Matched Analysis: Results for Outcomes One year Post-index Date through Difference-in-differences

	Rate or Mean (95% CI [†])		Pre-post difference, IRR (95% CI [†])	Difference-in differences (95% CI [†])
Measure: Group	Before index date	After index date		
Acute hospitalizations, #				
PACE in MM intervention group	0.44 (0.28-0.69)	0.49 (0.26-0.90)	1.11 (0.59-2.10)	1.67 (0.82-3.38)
Comparator group	0.38 (0.30-0.50)	0.26 (0.18-0.36)	0.67 (0.50-0.89)	
Emergency department visits				
PACE in MM intervention group	1.37 (1.04-1.72)	0.95 (0.64-1.44)	0.70 (0.42-1.16)	0.93 (0.54-1.60)
Comparator group	1.34 (0.89-2.13)	1.01 (0.76-1.35)	0.76 (0.61-0.94)	
Costs, \$				
PACE in MM intervention group	\$20,163 (\$14,945-\$27,202)	\$19,788 (\$14,200-\$27,574)	0.98 (0.68-1.43)	1.09 (0.70-1.68)
Comparator group	\$19,098 (\$15,100-\$24,156)	\$17,267 (\$12,699-\$23,477)	0.90 (0.76-1.08)	
30-day hospital readmissions, %				
PACE in MM intervention group	28.33 (17.93- 44.75)	27.88 (13.07-59.47)	0.98 (0.44-2.19)	1.00 (0.39-2.60)
Comparator group	19.40 (13.55-27.78)	19.02 (11.61-31.15)	0.98 (0.58-1.66)	
7-day follow up with FP, %				
PACE in MM intervention group	35.01 (22.94-53.44)	49.94 (40.34-61.82)	1.43 (0.93-2.19)	1.81 (0.99-3.30)
Comparator group	35.73 (28.26-45.19)	28.21 (19.47-40.87)	0.79 (0.51-1.22)	
Note: CI=95% confidence interval				

[†] CI = confidence interval

Figure 1. Propensity-matched Analysis Study Hierarchy



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APPENDICES

Appendix 1: Administrative datasets used in this study

Dataset	Description	Variables
Registered Persons Database (RPDB)	A population-based registry that contains demographic information for all residents of Ontario who have registered for health insurance.	Age, Sex, Geographic location, Death
Canadian Institute for Health Information Discharge Abstract Database (DAD)	Contains administrative and clinical information on all admissions/discharges from acute care facilities in Ontario	Inpatient hospital episodes, readmissions, chronic conditions, , costs
National Ambulatory Care Reporting System (NACRS)	Contains patient-level data (demographic, diagnoses, procedures) for all visits made to hospital and community based ambulatory care centres (emergency departments, day surgery, dialysis, cancer care clinics) in Ontario	Emergency department visits, costs
Ontario Mental Health Reporting System (OMHRS)	Contains data on adult designated inpatient mental health beds (incl. general, provincial psychiatric, and specialty psychiatric facilities) using the Resident Assessment Instrument - Mental Health	costs
Ontario Health Insurance Plan Claims Database (OHIP)	Claims for all physician services provided to Ontario residents	Chronic conditions, physician visits, post-discharge follow up, costs
Institute for Clinical Evaluative Sciences Physician Database (IPDB)	Yearly information on all physicians practicing in Ontario, including main specialty	Physician visits
Client Agency Program Enrolment (CAPE)	Contains a roster of patients that have registered with a primary care organization in Ontario, including a patients' association to specific physician and enrolment model type	Cost
National Rehabilitation Reporting System (NRS)	Contains client data collected from adult inpatient rehabilitation facilities in Ontario	Cost
Corporate Provider Database (CPDB)	Contains information about health care providers in Ontario, including program eligibility information	Cost
2006 Canadian Census (Census)	Contains aggregated, area-level data for Ontario and Canada that describes demographic information of the population, including markers not captured with health administrative data	Rurality, Income
Continuing Care Reporting System (CCRS)	Contains clinical and demographic information on residents receiving facility-based continuing care services in Ontario	Costs
Home Care Database (HCD)	Visits for all publicly-funded home care services provided to Ontario residents	Costs
Ontario Drug Benefit Claims (ODB)	Contains information on public and private patient prescription claims for drug benefits	Chronic conditions, costs
Same Day Surgery Database (SDS)	Information on same day surgeries performed in Ontario	Chronic conditions, costs
Yearly Health Services Contact (CONTACT)	Contains data on eligibility for services covered under OHIP	Ontario Health Insurance Plan (OHIP) eligibility

Appendix 2: Definitions of Outcomes

Acute hospitalizations: included all urgent acute hospital admissions taking place during the 1-year pre- or post-index period (DAD data). All causes of hospitalization were included, except for external causes of hospitalization, or where the admission category was for newborns or stillbirths. Only the first separation in a hospital episode was considered (i.e., transfers were excluded).

Emergency department (ED) visits: included all unplanned visits to an Ontario emergency department during the 1-year pre- or post-index period that did not result in an inpatient stay (NARCS data). All acuity levels were considered, and patients were limited to one visit per day.

Cost: included all health care expenditures that have been allocated to patient encounters for health care in the 1-year pre- or post-index period¹. Cost are in \$2018 CAD. Out of pocket expenses or insurance compensation paid out by third-party payers are not considered in this costing methodology.

30-day readmissions: included all index acute hospitalization episodes where the patient was discharged during the 1-year pre- or post-index period (DAD data). Index hospitalization episodes were excluded if the patient died in hospital, was discharged against medical advice, or if the discharge date was in the last 30-days of the pre- or post-index period (to allow for complete follow-up). For each index event, we then followed the patient prospectively for 30 days to identify any urgent inpatient readmissions for any cause.

7-day primary care follow-up: included all index acute hospitalization episodes where the patient was discharged during the 1-year pre- or post-index period (DAD data). Index hospitalization episodes were excluded if the patient died in hospital, was discharged against medical advice, or if the discharge date was in the last 7-days of the pre- or post-index period (to allow for complete follow-up). For each index event, we then followed the patient prospectively for 7 days to identify whether a visit to a primary care physician occurred (OHIP and IPDB data).

For each indicator, pre- and post-index measures were combined into a longitudinal dataset for analysis (one record per person, pre- and post-index).

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¹Wodchis WP, Bushmeneva K, Nikitovic M, McKillop I. Guidelines on Person Level Costing Using Administrative Databases in Ontario. Working Paper Series. Vol 1. Toronto: Health System Performance Research Network; 2013.

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Appendix 3: Definitions for 17 conditions used to define multimorbidity in ICES data

Condition	ICD 9 / OHIP	ICD 10	ODB*
Acute Myocardial Infarction (AMI)	410	I21, I22	
Osteo- and other Arthritis:			
(A) Osteoarthritis	715	M15-M19	
(B) Other Arthritis (includes Synovitis, Fibrositis, Connective tissue disorders, Ankylosing spondylitis, Gout Traumatic arthritis, pyogenic arthritis, Joint derangement, Dupuytren's contracture, Other MSK disorders)	727, 729, 710, 720, 274, 716, 711, 718, 728, 739	M00-M03, M07, M10, M11-M14, M20-M25, M30-M36, M65-M79	
Arthritis - Rheumatoid arthritis	714	M05-M06	
Asthma	493	J45, J46	
(all) Cancers	140-239	C00-C26, C30-C44, C45-C97	
Cardiac Arrhythmia	427 (OHIP) / 427.3 (DAD)	I48.0, I48.1	
Congestive Heart Failure	428	I500, I501, I509	
Chronic Obstructive Pulmonary Disease	491, 492, 496	J41, J43, J44	
Coronary syndrome (excluding AMI)	411-414	I20, I22-I25	
Dementia	290, 331 (OHIP) / 046.1, 290.0, 290.1, 290.2, 290.3, 290.4, 294, 331.0, 331.1, 331.5, F331.82 (DAD)	F00, F01, F02, F03, G30	Cholinesterase Inhibitors
Diabetes	250	E08 - E13	
Hypertension	401, 402, 403, 404, 405	I10, I11, I12, I13, I15	

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(Other) Mental Illnesses	291, 292, 295, 297, 298, 299, 301, 302, 303, 304, 305, 306, 307, 313, 314, 315, 319	F04, F050, F058, F059, F060, F061, F062, F063, F064, F07, F08, F10, F11, F12, F13, F14, F15, F16, F17, F18, F19, F20, F21, F22, F23, F24, F25, F26, F27, F28, F29, F340, F35, F36, F37, F430, F439, F453, F454, F458, F46, F47, F49, F50, F51, F52, F531, F538, F539, F54, F55, F56, F57, F58, F59, F60, F61, F62, F63, F64, F65, F66, F67, F681, F688, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79, F80, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F931, F932, F933, F938, F939, F94, F95, F96, F97, F98
Mood, anxiety, depression and other nonpsychotic disorders	296, 300, 309, 311	F30, F31, F32, F33, F34 (excl. F34.0), F38, F39, F40, F41, F42, F43.1, F43.2, F43.8, F44, F45.0, F45.1, F45.2, F48, F53.0, F68.0, F93.0, F99
Osteoporosis	733	M81, M82
Renal failure	403, 404, 584, 585, 586, v451	N17, N18, N19, T82.4, Z49.2, Z99.2
Stroke (excluding transient ischemic attack)	430, 431, 432, 434, 436	I60-I64
NOTES:		
Abbreviations: ICD = International Classification of Disease; ODB = Ontario Drug Benefit program database; OHIP = Ontario Health Insurance Plan, physician billings database;		
Conditions use all data available with the exception of AMI (1 year prior to index), Cancer (2 years), Mood Disorder (2 years) and Other Mental Illnesses (2 years)		
AMI, Asthma, COPD, CHF, Dementia, Diabetes and Hypertension are based on validated case algorithms (see Sources 1-7 below, respectively). All other conditions required at least one diagnosis recorded in acute care (CIHI) or two diagnoses recorded in physician billings within a two-year period. Dementia, however, required at least one acute record, three or more physician billings within 2 years and separated by 30 days or more, or any prescription dispensing of a cholinesterase inhibitor (see Source 5 below)		
*ODB prescription drug records are not available for the majority of persons under the age of 65		

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