BMC Primary Care

RESEARCH

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Assessing the impact of attachment to primary care and unattachment duration on healthcare utilization and cost in Ontario, Canada: a population-based retrospective cohort study using health administrative data

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Abstract

Background Insufficient access to primary care remains a major public health issue in Ontario, Canada, particularly for unattached residents (i.e., those who are not formally enrolled with a primary care provider, usually a family physician or occasionally a nurse practitioner). This study evaluates healthcare utilization and costs among unattached individuals, focusing on the impact of unattachment duration.

Methods We conducted a population-based retrospective cohort study using health administrative data, comparing provincially insured residents who maintained a consistent attachment status over the 12-month period (April 1, 2021, to March 31, 2022) to those who were unattached. We employed multivariable regression analyses to examine the associations between attachment status, duration of unattachment, demographic and patient health characteristics, and healthcare utilization and costs.

Results Prolonged periods of unattachment to primary care were significantly associated with increased healthcare costs, particularly in populations with a higher burden of comorbidities. In the context of healthcare costs, attached residents with low comorbidities had a median cost of $287, increasing to $3,711 (cost ratio: 12.93, CI: 12.86–13.01, $p < 0.0001$) for those with high comorbidities. Unattached individuals with low comorbidities had a median cost of $238 (cost ratio: 0.83, CI: 0.82–0.83, $p < 0.0001$), rising to $7,106 (cost ratio: 24.76, CI: 24.27–25.26, $p < 0.0001$) for high comorbidities, and up to $8,177 (cost ratio: 28.49, CI: 26.61–30.49, $p < 0.0001$) for long-term unattached with high comorbidities.

Conclusions Our findings underscore the substantial impact of long-term unattachment on both individual patients and the healthcare system, with higher levels of chronic disease further exacerbating these effects. These results

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are crucial for shaping programs and policies to maximize their impact on reducing emergency department visits, hospitalizations, and overall healthcare costs.

Keywords Primary care, Patient attachment, Unattachment duration, Comorbidity, Healthcare utilization, Healthcare costs, Healthcare policy

Background

Primary care providers (PCPs) play a pivotal role in a robust healthcare system, providing a broad range of medical care (screening, diagnosis and treatment), serving as navigators to the healthcare system, and coordinating most of a patient's medical care throughout their life. They provide services and opportunities to foster effective health promotion, disease prevention and chronic disease management, while also managing acute and chronic conditions [1]. In Canada, family doctors manage nearly 70% of all healthcare visits, with primary care consultations being approximately 30 times more frequent than hospital admissions [2]. To facilitate access to primary care, many countries have adopted a system of patient-provider "attachment", also known as rostering, enrollment, or patient registration [3]. This policy, a major focus in Canada since the early 2000s, aims to guarantee access to a regular PCP responsible for a patient's care [4]. Nevertheless, Canada underperforms as compared to most high-income countries, with approximately 15% of its population lacking a PCP [5]. Additionally, access to a regular PCP may be worsening, with 6.5 million Canadians lacking one in 2022, up from 4.5 million in 2019 [6]. A similar decline has been observed in the United States [7].

Studies indicate that unattachment can lead to care fragmentation or the absence of care and result in shifts in healthcare utilization patterns [8]. Unattached individuals may rely more on walk-in clinics, emergency departments (EDs) or specialist care instead of primary care, leading to higher costs, poorer patient outcomes, and increased mortality rates [8–11]. Notably, research suggests that being unattached is associated with a 40% increase in premature mortality rates [11]. Moreover, primary care attachment is inherently dynamic. An international scoping review highlights the diverse attachment trajectories patients follow – including gaining, losing or transferring providers – each of which, along with the duration of attachment and unattachment, can impact both patient outcomes and healthcare system performance [12].

Ontario currently has approximately 2.3 million residents without a family physician, with an additional 1.75 million attached to one already aged over 65 [13, 14]. Projections suggest that by 2026, 4.4 million residents or approximately 1 in 4 Ontarians will lack a PCP [5]. As the prevalence of individuals without access to primary care continues to rise across many high-income countries, a notable gap remains in the literature on how attachment status and unattachment duration influence healthcare utilization and costs. Furthermore, the relationship between demographic and health characteristics and attachment-related outcomes is not well understood. Limited research has explored the implications of unattachment duration in Ontario. Existing studies suggest that longer durations of unattachment are associated with poorer patient experiences and decreased engagement in preventive healthcare activities within this population [15, 16]. Therefore, the primary objective of this study was to describe and compare the demographic and patient health characteristics of the unattached population in Ontario. The secondary objective was to investigate the relationship between attachment status and healthcare utilization and costs, with a particular emphasis on unattachment duration. Initial analyses identified multimorbidity (the presence of two or more coexisting conditions in an individual) as a major contributor to healthcare utilization and costs, prompting us to stratify our planned models by number of comorbidities.

Methods

Study design and setting

We conducted a retrospective cohort study in accordance with the RECORD extension of the STROBE statement [17], to analyze the consequences of attachment status and unattachment duration, as well as demographic and health characteristics of the unattached population. Our analysis was based on health administrative data hosted at ICES, 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.

Our study was set in Ontario, Canada's most populous province. Ontario operates a universal, publicly funded healthcare system that covers medically necessary physician and hospital services, in addition to some home care and rehabilitation services [18]. In Ontario, residents can register with Health Care Connect, a provincially funded centralized system that helps match unattached individuals with doctors or nurse practitioners accepting new patients in their community. Alternatively, they can contact family practices directly to inquire about availability [19].

Study population

We analyzed a cohort of individuals residing in Ontario from April 1, 2021, to March 31, 2022. We excluded those who died during the observation window, did not reside in Ontario, or were ineligible for provincially funded healthcare. To qualify for the Ontario Health Insurance Plan (OHIP), an individual must be a Canadian citizen or have an eligible immigration status, reside primarily in Ontario, and be physically present for at least 153 days per year. We excluded those not in the Primary Care Population (PCPOP) database. PCPOP defines residents as "attached" if they are formally rostered to an eligible physician within a primary care enrollment model, which requires the patient to have signed an official enrollment form. "Non-enrolled care" refers to individuals not formally enrolled but who accessed primary care (e.g., under a fee-for-service or walk-in clinic model). Individuals who were not formally enrolled and lacked any type of primary care billing claims were classified as "unattached". We included only individuals with consistent attachment status over the period defined above, namely those who were attached, receiving non-enrolled care, or unattached on both April 1, 2021, and March 31, 2022.

Data sources

Our study utilized population-level health administrative datasets. These datasets were linked using unique encoded identifiers and analyzed at ICES. PCPOP was utilized to identify all eligible Ontario residents. Demographic data were derived from the Registered Persons Database (RPDB). Healthcare utilization was described using the Discharge Abstract Database (DAD) for hospital usage, the National Ambulatory Care Reporting System (NACRS) for ED visits, and OHIP for physician encounters. Costs were calculated using a previously validated approach derived from several healthcare utilization databases: DAD, OHIP, NACRS, Same Day Surgery (SDS), Continuing Care Reporting System (CCRS), Home Care Database (HCD), Ontario Mental Health Reporting System (OHMRS) and Ontario Drug Database (ODB) [20].

We used PCPOP to define our study cohort and variables, including the classifications of attached, non-enrolled care, and unattached. PCPOP was also used to determine the duration of unattachment by tracing attachment status on April 1 of each year, extending up to 15 years prior to the index date. During this period, formal attachment and associated incentives were established in Ontario [21]. We reported demographic and health characteristics, including age, sex, material deprivation, comorbidities, rurality, healthcare utilization, and costs. Material deprivation was measured using the Ontario Marginalization Index [22]. The Johns Hopkins ACG® System Version 10 Aggregated Diagnosis Groups (ADGs) was used to account for the number of comorbidities, by assigning 1–32 ADGs to each patient based on International Classification of Disease (ICD) codes [23]. We categorized individuals as rural if they resided outside of areas with a population of at least 1,000 and a density of 400 or more people per square kilometre [24]. We identified chronic diseases (chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), diabetes, hypertension, and dementia), using cohorts created based on validated case definitions used at ICES. Those with at least two mental health OHIP claims or one mental health hospitalization, excluding dementia, were classified as having a mental health diagnosis [25].

Main outcomes

Outcomes included the occurrence (yes/no) and number of ED visits and hospital admissions between April 1, 2021, and March 31, 2022. Total healthcare costs were estimated using a person-level costing approach to determine the annual expenses from the perspective of the health system payer, the Ontario Ministry of Health. We used health utilization data, including hospital resource intensity weights, from administrative databases and corresponding costing information [20]. Costs are reported in Canadian dollars (CAD) and adjusted to the year 2021.

Statistical analyses

To compare patient characteristics, health utilization and costs of the unattached, non-enrolled care, and attached populations, we used one-way ANOVAs for continuous variables and chi-square tests for categorical variables, using the median and Kruskal-Wallis test for cost variables to account for skewness. To describe the unattached population, we categorized the number of years unattached (in years: <2, 2–4, 5–9, 10–14, 15+), based on visual examination of the distribution and clinical expertise from family physicians (JF and LB). We labeled these categories as "recently unattached" (<2 years), "short-term unattached" (2–4 years), "moderate-term unattached" (5–9 years), "long-term unattached" (10–14 years) and "very long-term unattached" (15+ years). We compared different characteristics among the categorized durations of unattachment using descriptive statistics as described above. We introduced a "missing" category for missing data.

To investigate the relationship between attachment status and emergency department use, hospital use, and costs, we used multivariable regression models, first using attachment status as the main exposure variable, and then creating new attachment categories by the number of ADGs or the presence of single comorbidities. Lastly, we developed an exposure variable by stratifying "attachment status" with both "duration of unattachment" and "ADGs". These decisions were made

post-hoc, following preliminary analyses, including bivariate analyses and adjusted regression models using only attachment status as the exposure. We used logistic regression models to analyze health utilization, defining the outcomes as having at least one ED visit or hospitalization during the study period. We used gamma generalized linear models with log links to model the total 1-year healthcare cost. All models were adjusted for sex, age, rural residence, and income quintile. To prevent collinearity, models were either adjusted for total ADGs or for the 6 individual comorbidities. All statistical analyses were conducted using SAS Enterprise Guide 7.1 [26].

Results

The initial study sample, including all PCPOP 2021 and 2022 inclusion cohorts, comprised 14,487,217 individuals. After excluding those who died, non-residents of Ontario during the observation period, and those who changed their rostering status between April 1, 2021, and April 1, 2022, the final cohort comprised 13,126,740 individuals (Fig. 1).

Describing attachment status

The percentage of unattached individuals was 14.78%, while 6.57% received non-enrolled care. Unattached individuals had lower comorbidity levels, as measured by ADGs, with a mean score 52% lower than that of the attached group (1.54 vs. 2.94). Conversely, the non-enrolled care group had the highest comorbidity levels (3.21), with scores twice as high as those of the unattached group and 9% higher than the attached group (Table 1). The attached group was the oldest, with a mean age of 44.74 years, followed by the non-enrolled care group, which had a mean age of 37.22 years, and the unattached group (mean age 34.91 years) (Table 1). Table 2 describes the healthcare utilization patterns based on attachment status. The non-enrolled care group had the highest mean number of ED visits (0.45), with an average 32% higher than the attached group (0.34) and 50% higher than the unattached group (0.30). However, this group exhibited similar hospitalizations, hospital length of stay, and total healthcare costs compared to the attached group. The unattached group had the lowest rates of healthcare utilization and costs.

Describing unattachment duration

Table 3 describes unattached individuals by unattachment duration. Among the 1,940,137 unattached individuals, nearly half (45.62%) had been unattached for over five years, and 12.4% had been unattached for over 15 years. Age increased incrementally based on unattachment duration, from an average of 31.25 years in

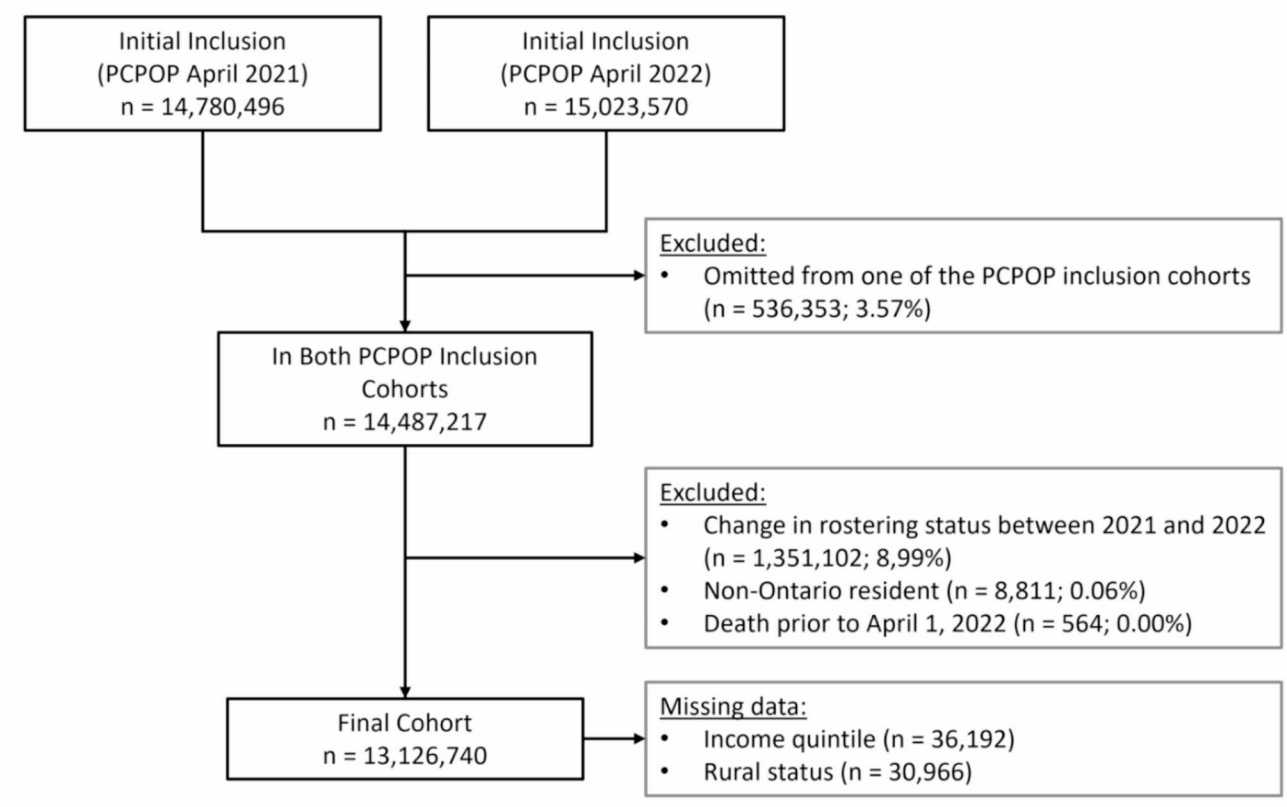

Fig. 1 Participant Selection Flow Diagram

Table 1 Demographic and health characteristics by attachment status

Sociodemographic Variables	Value	Unattached	Non-Enrolled Care	Attached	Total
		N **= 1,940,137**	***N*** **= 862,476**	***N*** **= 10,324,127**	***N*** **= 13,126,740**
		14.78%	**6.57%**	**78.65%**	**100.00%**
Age at index date (April 1, 2021) in years	Mean (SD)	34.91 (22.50)	37.22 (22.43)	44.74 (22.67)	42.80 (22.94)
	1–4 years	126,568 (6.52%)	66,556 (7.72%)	255,753 (2.48%)	448,877 (3.42%)
	5–9 years	175,724 (9.06%)	55,029 (6.38%)	451,945 (4.38%)	682,698 (5.20%)
	10–14 years	167,666 (8.64%)	41,995 (4.87%)	517,630 (5.01%)	727,291 (5.54%)
	15–17 years	81,063 (4.18%)	25,352 (2.94%)	326,231 (3.16%)	432,646 (3.30%)
	18–34 years	482,992 (24.89%)	229,429 (26.60%)	2,059,407 (19.95%)	2,771,828 (21.12%)
	35–49 years	370,555 (19.10%)	175,612 (20.36%)	2,081,922 (20.17%)	2,628,089 (20.02%)
	50–64 years	308,282 (15.89%)	154,377 (17.90%)	2,355,785 (22.82%)	2,818,444 (21.47%)
	65–79 years	169,911 (8.76%)	87,585 (10.16%)	1,698,748 (16.45%)	1,956,244 (14.90%)
	80 + years	57,376 (2.96%)	26,541 (3.08%)	576,706 (5.59%)	660,623 (5.03%)
Sex on RPDB	F	838,998 (43.24%)	442,601 (51.32%)	5,415,696 (52.46%)	6,697,295 (51.02%)
	M	1,101,139 (56.76%)	419,875 (48.68%)	4,908,431 (47.54%)	6,429,445 (48.98%)
2004 rurality index for Ontario	Mean (SD)	13.74 (18.05)	12.14 (15.49)	15.41 (18.01)	14.95 (17.88)
Rural status	Urban	1,712,730 (88.28%)	800,145 (92.77%)	9,183,189 (88.95%)	11,696,064 (89.10%)
	Rural	219,857 (11.33%)	59,886 (6.94%)	1,119,967 (10.85%)	1,399,710 (10.66%)
Income quintile	1 (lowest)	487,844 (25.14%)	181,902 (21.09%)	1,783,783 (17.28%)	2,453,529 (18.69%)
	2	394,824 (20.35%)	170,505 (19.77%)	1,962,197 (19.01%)	2,527,526 (19.25%)
	3	363,952 (18.76%)	175,025 (20.29%)	2,126,391 (20.60%)	2,665,368 (20.30%)
	4	347,377 (17.90%)	169,831 (19.69%)	2,204,444 (21.35%)	2,721,652 (20.73%)
	5 (highest)	337,649 (17.40%)	162,493 (18.84%)	2,222,331 (21.53%)	2,722,473 (20.74%)
Total number of ADGs	Mean (SD)	1.54 (2.32)	3.21 (2.78)	2.94 (2.75)	2.75 (2.74)
	0–5 (low)	1,801,105 (92.83%)	707,733 (82.06%)	8,639,076 (83.68%)	11,147,914 (84.93%)
	6–9 (moderate)	113,568 (5.85%)	125,063 (14.50%)	1,387,989 (13.44%)	1,626,620 (12.39%)
	10+ (high)	25,464 (1.31%)	29,680 (3.44%)	297,062 (2.88%)	352,206 (2.68%)
COPD (diagnosis prior to index)		20,596 (1.06%)	13,994 (1.62%)	213,986 (2.07%)	248,576 (1.89%)
CHF (diagnosis prior to index)		18,638 (0.96%)	12,253 (1.42%)	202,982 (1.97%)	233,873 (1.78%)
Diabetes (diagnosis prior to index)		79,150 (4.08%)	64,863 (7.52%)	1,043,574 (10.11%)	1,187,587 (9.05%)
Mental health in last 2 years		203,198 (10.47%)	228,929 (26.54%)	2,174,009 (21.06%)	2,606,136 (19.85%)
Hypertension (diagnosis prior to index)		201,122 (10.37%)	148,236 (17.19%)	2,514,636 (24.36%)	2,863,994 (21.82%)
Dementia (diagnosis prior to index)		16,069 (0.83%)	8,020 (0.93%)	111,948 (1.08%)	136,037 (1.04%)

Note: Hypothesis testing yielded significant p−values. Column percentages are reported for categorical variables. SD: standard deviation, IQR: interquartile range, ED: emergency department, RIO: rurality index of Ontario, ADG: aggregated diagnostic group, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, LOS: length of stay

the recently unattached group to 47.85 years in the very long-term unattached group. Comorbidity levels (as per ADGs) included a mean ADG score of 1.75 for the recently unattached group, decreasing to 1.24 (71%) in the moderate term unattached group, and rising again to 2.01 (115%) in the very long-term unattached group. We noted a similar pattern in healthcare utilization, including ED visits, hospitalizations, hospital length of stay, and costs (Table 4).

Regression models – sociodemographic characteristics

In the adjusted models, before stratifying by attachment status and unattachment duration, sociodemographic variables – such as rurality, age and income quintile – were significant drivers of healthcare utilization and costs. Compared to urban residents, individuals living in a rural setting were twice as likely to have an ED visit (adjusted odds ratio: 2.07, CI: 2.06–2.07, $p < 0.0001$), 50% more likely to be hospitalized (adjusted odds ratio: 1.50, CI: 1.49–1.51, $p < 0.0001$) and incurred 10% higher median healthcare costs (adjusted cost ratio: 1.10, CI: 1.10–1.11, $p < 0.0001$). Similarly, income level and age were strongly associated with differences. Ontarians in the highest income quintile incurred 20% lower median healthcare costs compared to those in the lowest income quintile (adjusted cost ratio: 0.80, CI: 0.80–0.80, $p < 0.0001$). Individuals aged 85 and older incurred over six times the total median healthcare costs of those aged 18–34 (adjusted cost ratio: 6.54, CI: 6.51–6.57, $p < 0.0001$). By contrast, sex had a smaller and inconsistent effect on ED visits, hospitalizations and costs (Supplementary Tables 3–5).

Table 2 Healthcare utilization and cost by attachment status

Variables	Value	Unattached	Non-Enrolled Care	Attached	Total
		N **= 1,940,137**	***N*** **= 862,476**	***N*** **= 10,324,127**	***N*** **= 13,126,740**
At least 1 ED visit (1 year)		316,549 (16.32%)	210,577 (24.42%)	2,135,567 (20.69%)	2,662,693 (20.28%)
Total ED visits (1 year)	Mean ± SD	0.30 (1.25)	0.45 (1.46)	0.34 (1.00)	0.34 (1.08)
At least 1 hospitalization (1 year)		51,321 (2.65%)	41,046 (4.76%)	476,323 (4.61%)	568,690 (4.33%)
Number of hospitalizations (1 year)	Mean ± SD	0.04 (0.28)	0.06 (0.36)	0.06 (0.33)	0.06 (0.32)
Total LOS (1 year)	Mean ± SD	0.24 (3.56)	0.38 (4.29)	0.36 (3.82)	0.35 (3.82)
Total cost adjusted to 2021 (1 year)	Mean ± SD	1622.91 (10738.26)	2438.39 (10732.50)	2409.34 (9679.32)	2295.02 (9918.45)
	Median (IQR)	37 (0-401)	311 (68-1224)	398 (147–1367)	331 (106–1209)
ED cost	Mean ± SD	76.32 (389.79)	122.44 (484.66)	97.72 (348.98)	96.18 (365.76)
	Median (IQR)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Hospital cost	Mean ± SD	269.97 (3889.38)	447.86 (4827.32)	424.30 (4361.66)	403.04 (4328.09)
	Median (IQR)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Cost of total physician visits	Mean ± SD	304.77 (1153.10)	614.95 (1495.64)	557.87 (1307.86)	524.21 (1302.82)
	Median (IQR)	0 (0-201)	186 (38–582)	165 (25–556)	139 (0-506)
Cost of total FFS GP visits	Mean ± SD	74.79 (627.02)	174.75 (651.36)	105.67 (433.01)	105.65 (483.64)
	Median (IQR)	0 (0–10)	74 (0-171)	7 (0–97)	0 (0–93)
Cost of total FFS specialist visits	Mean ± SD	193.15 (792.51)	382.56 (1112.73)	370.97 (1027.95)	345.45 (1004.63)
	Median (IQR)	0 (0–97)	38 (0-321)	36 (0-325)	11 (0-288)

Note: Hypothesis testing yielded significant p–values, except for those marked with *. Column percentages are provided for categorical variables. SD: standard deviation, IQR: interquartile range, ED: emergency department, LOS: length of stay, FFS: Fee–for–service, GP: General Practitioner/Family Physician. Costs are reported in CAD, adjusted to 2021

Regression models - comorbidities

Comorbidities emerged as the primary contributor to healthcare utilization and costs (Table 5). After adjusting for relevant covariates, individuals with 10+ ADGs incurred significantly higher healthcare costs and utilization, regardless of attachment status or unattachment duration. Within the attached group, an individual with 10+ ADGs had total median healthcare costs 13 times higher ($3,710 vs. $287; adjusted cost ratio: 12.93, CI: 12.86–13.01, $p < 0.0001$), was 29 times more likely to utilize the ED at least once (adjusted odds ratio: 29.22, CI: 28.95–29.50, $p < 0.0001$), and 50 times more likely to be hospitalized at least once (adjusted odds ratio: 49.60, CI: 49.13–50.07, $p < 0.0001$) throughout the study period than an individual with 0–5 ADGs. When examining specific diseases, dementia, and mental health-related issues emerged as the most significant cost drivers (Table 6).

Regression models – attachment status and duration

Our adjusted regression models stratified by comorbidity indicated that both the non-enrolled care and unattached groups experienced increased healthcare utilization and costs, with these effects being more pronounced in those who had been unattached for longer durations. This pattern persisted only among individuals with moderate to high comorbidity levels and was absent in individuals with low comorbidities. Specifically, attached individuals with low comorbidities incurred a median healthcare cost of $287, whereas those attached with high comorbidities incurred costs escalating to $3,711 (adjusted cost ratio: 12.93, CI: 12.86–13.01, $p < 0.0001$). Costs further increased to $4,730 in the non-enrolled care group (adjusted cost ratio: 16.48, CI: 16.18–16.79, $p < 0.0001$) and to $7,106 in the unattached group (adjusted cost ratio: 24.76, CI: 24.27–25.26) (Table 5). Costs rose even higher based on unattachment duration, with long-term unattached individuals incurring healthcare costs of $8,177 (adjusted cost ratio: 28.49, CI: 26.62–30.49, $p < 0.0001$). A noticeable tail-off was observed in the very long-term unattached group, which incurred a cost of $4,830 (adjusted cost ratio: 16.83, CI: 16.13–17.57, $p < 0.0001$). A similar pattern was observed for ED visits and hospitalizations, where comorbidities, attachment status, and unattachment duration increased healthcare utilization, except for a notable tail-off in the very long-term unattached group (Table 7).

Discussion

We conducted a population-based retrospective cohort study to investigate the relationship between demographic and health characteristics, attachment status, and unattachment duration in relation to healthcare utilization and costs. Our findings can be distilled into four principal points: First, comorbidities were the most significant contributors to healthcare utilization and costs, with the importance of formal attachment and accessing primary care becoming particularly pronounced in groups with moderate to high comorbidity. Second, our findings emphasize the critical importance of ensuring formal patient attachment; residents accessing primary care without formal attachment (non-enrolled care) consistently experienced worse outcomes and higher costs.

Table 3 Demographic and health characteristics by unattachment duration

Sociodemographic Variables	Value	Unattachment Duration					
		< 2 Years	2–4 years	5–9 years	10–14 years	15 + years	Total
		N = 412,614	*N* = 642,561	*N* = 443,622	*N* = 200,788	*N* = 240,552	*N* = 1,940,137
		21.27%	33.12%	22.87%	10.35%	12.40%	
Age at index date (April 1, 2021) in years	Mean (SD)	31.25 (21.38)	32.18 (21.99)	34.53 (22.74)	36.48 (22.44)	47.85 (20.52)	34.91 (22.50)
	1–4 years	52,454 (12.71%)	74,114 (11.53%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	126,568 (6.52%)
	5–9 years	29,161 (7.07%)	57,493 (8.95%)	89,070 (20.08%)	0 (0.00%)	0 (0.00%)	175,724 (9.06%)
	10–14 years	26,217 (6.35%)	45,959 (7.15%)	36,762 (8.29%)	58,728 (29.25%)	0 (0.00%)	167,666 (8.64%)
	15–17 years	12,593 (3.05%)	22,147 (3.45%)	17,546 (3.96%)	8,011 (3.99%)	20,766 (8.63%)	81,063 (4.18%)
	18–34 years	131,898 (31.97%)	173,424 (26.99%)	90,865 (20.48%)	34,411 (17.14%)	52,394 (21.78%)	482,992 (24.89%)
	35–49 years	75,903 (18.40%)	123,537 (19.23%)	89,004 (20.06%)	36,859 (18.36%)	45,252 (18.81%)	370,555 (19.10%)
	50–64 years	51,175 (12.40%)	86,813 (13.51%)	68,759 (15.50%)	35,335 (17.60%)	66,200 (27.52%)	308,282 (15.89%)
	65–79 years	24,370 (5.91%)	43,694 (6.80%)	37,662 (8.49%)	21,274 (10.60%)	42,911 (17.84%)	169,911 (8.76%)
	80 + years	8,843 (2.14%)	15,380 (2.39%)	13,954 (3.15%)	6,170 (3.07%)	13,029 (5.42%)	57,376 (2.96%)
Sex on RPDB	F	180,970 (43.86%)	281,223 (43.77%)	195,384 (44.04%)	86,985 (43.32%)	94,436 (39.26%)	838,998 (43.24%)
	M	231,644 (56.14%)	361,338 (56.23%)	248,238 (55.96%)	113,803 (56.68%)	146,116 (60.74%)	1,101,139 (56.76%)
2004 rurality index for Ontario	Mean (SD)	12.56 (16.43)	13.53 (17.72)	13.73 (18.08)	15.74 (20.09)	14.70 (19.54)	13.74 (18.05)
Rural status	Urban	376,185 (91.17%)	575,147 (89.51%)	390,909 (88.12%)	167,150 (83.25%)	203,339 (84.53%)	1,712,730 (88.28%)
	Rural	34,860 (8.45%)	64,855 (10.09%)	50,855 (11.46%)	32,920 (16.40%)	36,367 (15.12%)	219,857 (11.33%)
Income quintile	1 (lowest)	102,216 (24.77%)	160,716 (25.01%)	111,443 (25.12%)	51,185 (25.49%)	62,284 (25.89%)	487,844 (25.14%)
	2	86,126 (20.87%)	130,432 (20.30%)	89,023 (20.07%)	39,544 (19.69%)	49,699 (20.66%)	394,824 (20.35%)
	3	80,401 (19.49%)	120,974 (18.83%)	81,047 (18.27%)	36,689 (18.27%)	44,841 (18.64%)	363,952 (18.76%)
	4	74,868 (18.14%)	116,914 (18.20%)	80,158 (18.07%)	34,959 (17.41%)	40,478 (16.83%)	347,377 (17.90%)
	5 (highest)	67,253 (16.30%)	110,695 (17.23%)	79,886 (18.01%)	37,587 (18.72%)	42,228 (17.55%)	337,649 (17.40%)
Total number of ADGs	Mean (SD)	1.75 (2.42)	1.48 (2.25)	1.24 (2.11)	1.42 (2.19)	2.01 (2.70)	1.54 (2.32)
	0–5 (low)	377,794 (91.56%)	600,730 (93.49%)	420,368 (94.76%)	188,758 (94.01%)	213,455 (88.74%)	1,801,105 (92.83%)
	6–9 (moderate)	28,931 (7.01%)	34,469 (5.36%)	18,726 (4.22%)	9,839 (4.90%)	21,603 (8.98%)	113,568 (5.85%)
	10+ (high)	5,889 (1.43%)	7,362 (1.15%)	4,528 (1.02%)	2,191 (1.09%)	5,494 (2.28%)	25,464 (1.31%)
COPD (diagnosis prior to index)		3,655 (0.89%)	5,822 (0.91%)	4,742 (1.07%)	2,354 (1.17%)	4,023 (1.67%)	20,596 (1.06%)
CHF (diagnosis prior to index)		3,248 (0.79%)	5,132 (0.80%)	4,144 (0.93%)	1,943 (0.97%)	4,171 (1.73%)	18,638 (0.96%)
Diabetes (diagnosis prior to index)		13,882 (3.36%)	21,676 (3.37%)	16,584 (3.74%)	7,714 (3.84%)	19,294 (8.02%)	79,150 (4.08%)
Mental health in last 2 years		44,584 (10.81%)	61,935 (9.64%)	39,041 (8.80%)	19,551 (9.74%)	38,087 (15.83%)	203,198 (10.47%)
Hypertension (diagnosis prior to index)		33,653 (8.16%)	55,550 (8.65%)	43,147 (9.73%)	20,195 (10.06%)	48,577 (20.19%)	201,122 (10.37%)
Dementia (diagnosis prior to index)		3,976 (0.96%)	5,649 (0.88%)	3,304 (0.74%)	1,134 (0.56%)	2,006 (0.83%)	16,069 (0.83%)

Note: Hypothesis testing yielded significant p−values. Column percentages are reported for categorical variables. SD: standard deviation, IQR: interquartile range, ED: emergency department, RIO: rurality index of Ontario, ADG: aggregated diagnostic group, COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure, LOS: length of stay

Third, the results highlight the necessity of accessing primary care in higher-comorbidity populations, as unattached individuals (those not attached and not accessing primary care services) incurred the highest healthcare costs and utilization. Fourth, the negative impacts of unattachment were exacerbated by longer unattachment durations, though a noticeable tail-off in the very-long term unattached suggest potential biases in our findings.

The first finding emphasizes the dominant role of multimorbidity in driving healthcare utilization and costs, followed by attachment status, and to a lesser extent, unattachment duration. Comorbidities play a substantial role in healthcare utilization and costs, as individuals

Table 4 Healthcare utilization, and cost by unattachment duration

Variables	Value	Unattachment Duration					
		< 2 Years	2–4 Years	5–9 Years	10–14 Years	15 + Years	Total
		N = 412,614	*N* = 642,561	*N* = 443,622	*N* = 200,788	*N* = 240,552	*N* = 1,940,137
At least 1 ED visit (1 year)		77,638 (18.82%)	106,642 (16.60%)	59,597 (13.43%)	31,137 (15.51%)	41,535 (17.27%)	316,549 (16.32%)
Total ED visits (1 year)	Mean ± SD	0.34 (1.25)	0.30 (1.26)	0.25 (1.29)	0.28 (1.12)	0.33 (1.26)	0.30 (1.25)
At least 1 hospitalization (1 year)		11,568 (2.80%)	15,485 (2.41%)	9,617 (2.17%)	5,526 (2.75%)	9,125 (3.79%)	51,321 (2.65%)
Number of hospitalizations (1 year)	Mean ± SD	0.04 (0.28)	0.03 (0.27)	0.03 (0.27)	0.04 (0.29)	0.05 (0.33)	0.04 (0.28)
Total LOS (1 year)	Mean ± SD	0.23 (3.54)	0.20 (3.17)	0.21 (3.20)	0.27 (3.63)	0.43 (4.92)	0.24 (3.56)
Total cost adjusted to 2021 (1 year)	Mean ± SD	1698.18 (10563.85)	1522.33 (10312.06)	1393.30 (10354.89)	1621.74 (10728.33)	2186.89 (12660.56)	1622.91 (10738.26)
	Median (IQR)	48 (0-466)	26 (0-349)	13 (0-263)	43 (0-433)	81 (0-761)	37 (0-401)
ED cost	Mean ± SD	84.21 (398.98)	74.81 (380.58)	64.19 (408.16)	73.29 (351.86)	91.68 (392.82)	76.32 (389.79)
	Median (IQR)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Hospital cost	Mean ± SD	273.16 (3874.97)	232.48 (3673.27)	227.62 (3600.71)	295.93 (4078.41)	421.10 (4731.25)	269.97 (3889.38)
	Median (IQR)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–0)
Cost of total physician visits	Mean ± SD	335.93 (1307.73)	280.62 (1131.46)	249.91 (976.57)	297.58 (1070.26)	423.00 (1278.02)	304.77 (1153.10)
	Median (IQR)	25 (0-252)	0 (0-180)	0 (0-129)	0 (0-193)	38 (0-336)	0 (0-201)
Cost of total FFS GP visits	Mean ± SD	91.01 (674.56)	71.80 (830.55)	57.86 (370.86)	57.32 (415.35)	100.72 (384.95)	74.79 (627.02)
	Median (IQR)	0 (0–37)	0 (0–0)	0 (0–0)	0 (0–0)	0 (0–84)	0 (0–10)
Cost of total FFS specialist visits	Mean ± SD	203.72 (795.10)	174.15 (740.77)	160.56 (728.03)	201.77 (798.16)	278.64 (997.89)	193.15 (792.51)
	Median (IQR)	0 (0-132)	0 (0–85)	0 (0–68)	0 (0-113)	0 (0-163)	0 (0–97)

Note: Hypothesis testing yielded significant p–values, except for those marked with *. Column percentages are provided for categorical variables. SD: standard deviation, IQR: interquartile range, ED: emergency department, LOS: length of stay, FFS: Fee–for–service, GP: General Practitioner/Family Physician. Costs are reported in CAD, adjusted to 2021

Table 5 ED visits, hospitalization, and total healthcare costs by attachment status and number of ADGs

Outcome	Total Number of ADGs	Attached	Non-Enrolled Care	Unattached
≥ 1 ED Visit	0–5 (low)	1 (REF)	1.16 (1.15, 1.16)	0.80 (0.79, 0.80)
	6–9 (moderate)	7.57 (7.54, 7.60)	8.54 (8.44, 8.64)	10.50 (10.37, 10.63)
	10+ (high)	29.22 (28.95, 29.50)	32.33 (31.39, 33.31)	37.31 (36.05, 38.61)
≥ 1 Hospitalization	0–5 (low)	1 (REF)	1.08 (1.06, 1.10)	0.67 (0.66, 0.68)
	6–9 (moderate)	10.52 (10.45, 10.60)	10.21 (10.04, 10.39)	14.60 (14.37, 14.84)
	10+ (high)	49.60 (49.13, 50.07)	45.94 (44.85, 47.06)	68.27 (66.53, 70.05)
Total 1-Year Cost (CAD; Adjusted to 2021)	0–5 (low)	287 (REF)	312.83 (309.96-312.83)	238.21 (235.34-238.21)
	6–9 (moderate)	1,208.27 (1,202.53-1,211.14)	1,412.04 (1,397.69-1,423.52)	1,931.51 (1,914.29-1,948.73)
	10+ (high)	3,710.91 (3,690.82-3,733.87)	4,729.76 (4,643.66-4,818.73)	7,106.12 (6,965.49 to 7,249.62)

Note: ED: emergency department, hosp: hospitalization, ADG: aggregated diagnostic group. Models adjusted for sex, age, rural residence, and income quintile. ED and hospitalization utilization are reported as adjusted odds ratios with 95% confidence intervals (logistic regression). Total healthcare costs are reported in CAD as the median value, with 95% confidence intervals. All p–values were <0.0001

with multiple health conditions typically require more frequent and intensive medical interventions, ongoing management, and coordinated care [27]. This impact of high-needs patients is well documented in the primary care literature. Our finding aligns with prior research, showing that, in Ontario, the top 5% of highest cost users account for over 60% of all healthcare costs and incur an average cost 12 times higher than that of the average use [28].

The second finding is that individuals accessing primary care without formal attachment (non-enrolled care) exhibited higher rates of ED use and higher costs, largely driven by ED and fee for service physician use compared to the attached group. This finding underscores the importance of formal patient attachment, particularly among those with multimorbidity [3]. However, caution is warranted in interpreting these results, as the "non-enrolled care" group includes only unattached individuals who accessed primary care, thereby excluding healthy

Table 6 Adjusted cost ratios by attachment status and individual chronic condition (gamma models)

Comorbidity Status	Attached	Non-Enrolled Care	Unattached
	Adjusted Cost Ratio (95% CI)	Adjusted Cost Ratio (95% CI)	Adjusted Cost Ratio (95% CI)
No COPD	1 (REF)	1.13 (1.13, 1.14)	0.85 (0.85, 0.86)
COPD	1.78 (1.77, 1.80)	2.29 (2.22, 2.35)	2.40 (2.35, 2.46)
No CHF	1 (REF)	1.14 (1.13, 1.14)	0.86 (0.85, 0.86)
CHF	2.23 (2.22, 2.25)	2.74 (2.66, 2.82)	2.56 (2.50, 2.63)
No Diabetes	1 (REF)	1.13 (1.12, 1.13)	0.84 (0.83, 0.84)
Diabetes	1.76 (1.75, 1.76)	2.14 (2.12, 2.17)	2.35 (2.32, 2.37)
No Mental Health	1 (REF)	1.09 (1.09, 1.10)	0.75 (0.75, 0.75)
Mental Health	2.17 (2.16, 2.17)	2.80 (2.78, 2.82)	3.87 (3.84, 3.90)
No Hypertension	1 (REF)	1.13 (1.12, 1.13)	0.82 (0.82, 0.83)
Hypertension	1.46 (1.46, 1.47)	1.70 (1.68, 1.71)	1.65 (1.64, 1.66)
No Dementia	1 (REF)	1.14 (1.13, 1.14)	0.85 (0.85, 0.86)
Dementia	3.49 (3.46, 3.53)	4.08 (3.93, 4.24)	5.74 (5.60, 5.90)

Note: COPD: chronic obstructive pulmonary disease, CHF: congestive heart failure. Models adjusted for sex, age, rural residence, and income quintile. All p−values were <0.0001

Table 7 ED visits, hospitalization, and total healthcare costs by duration of unattachment and number of ADGs

Outcome	Attachment Status	Total ADGs 0–5 (Low)	Total ADGs 6–9 (Moderate)	Total ADGs 10+ (High)
		Adjusted Ratios (95% CI)	Adjusted Ratios (95% CI)	Adjusted Ratios (95% CI)
≥ 1 ED Visit	Attached	1 (REF)	7.57 (7.53, 7.60)	29.20 (28.93, 29.48)
	Non-enrolled care	1.16 (1.15, 1.16)	8.54 (8.44, 8.64)	32.32 (31.37, 33.30)
	Unattached (< 2 years)	0.89 (0.88, 0.89)	10.50 (10.24, 10.76)	38.32 (35.60, 41.24)
	Unattached (2–4 years)	0.80 (0.79, 0.81)	11.02 (10.77, 11.27)	40.84 (38.21, 43.65)
	Unattached (5–9 years)	0.70 (0.69, 0.70)	11.70 (11.35, 12.05)	36.91 (34.05, 40.00)
	Unattached (10–14 years)	0.81 (0.80, 0.82)	12.78 (12.25, 13.33)	38.79 (34.47, 43.64)
	Unattached (15 + years)	0.80 (0.79, 0.81)	8.21 (7.99, 8.44)	32.54 (30.37, 34.86)
≥ 1 Hospitalization	Attached	1 (REF)	10.52 (10.44, 10.60)	49.58 (49.11, 50.05)
	Non-enrolled care	1.08 (1.06, 1.10)	10.21 (10.04, 10.39)	45.92 (44.83, 47.04)
	Unattached (< 2 years)	0.72 (0.70, 0.74)	13.83 (13.39, 14.28)	59.01 (55.99, 62.19)
	Unattached (2–4 years)	0.66 (0.64, 0.68)	14.43 (14.02, 14.85)	66.32 (63.28, 69.50)
	Unattached (5–9 years)	0.58 (0.56, 0.60)	16.65 (16.05, 17.28)	81.92 (77.14, 87.00)
	Unattached (10–14 years)	0.73 (0.70, 0.77)	19.06 (18.17, 20.00)	95.91 (87.86, 104.71)
	Unattached (15 + years)	0.70 (0.67, 0.73)	12.45 (12.01, 12.90)	62.50 (59.21, 65.98)
Total 1-Year Healthcare Cost (CAD; Adjusted to 2021)	Attached	287 (REF)	1,208.27 (1,202.53-1,211.14)	3,713.78 (3,690.82-3,733.87)
	Non-enrolled care	312.83 (309.96-312.83)	1,412.04 (1,397.69-1,423.52)	4,729.76 (4,643.66-4,818.73)
	Unattached (< 2 years)	246.82 (243.95-246.82)	1,871.24 (1,836.80-1,905.68)	7,387.38 (7,086.03-7,700.21)
	Unattached (2–4 years)	232.47 (232.47-232.47)	2,023.35 (1,988.91-2,057.79)	7,840.84 (7,553.84-8,136.45)
	Unattached (5–9 years)	223.86 (223.86-226.73)	2,296.00 (2,244.34-2,350.53)	7,800.66 (7,441.91-8,179.50)
	Unattached (10–14 years)	249.69 (246.82-249.69)	2,221.38 (2,149.63-2,293.13)	8,176.63 (7,639.94-8,750.63)
	Unattached (15 + years)	246.82 (243.95-246.82)	1,420.65 (1,389.08-1,452.22)	4,830.21 (4,629.31-5,042.59)

Note: ED: emergency department, ADG: aggregated diagnostic group. Models adjusted for sex, age, rural residence, and income quintile. ED and hospitalization utilization are reported as adjusted odds ratios with 95% confidence intervals (logistic regression). Total healthcare costs are reported in CAD as the median value, with 95% confidence intervals. All p−values were <0.0001

individuals who did not require care. This exclusion may contribute to the observed higher healthcare utilization. Nonetheless, this disparity may also stem from the fragmented and less coordinated care received by the non-enrolled care group, leading to increased redundancy and inefficiency in treatments [29]. Additionally, the lack of a consistent PCP may result in fewer health promotion and disease prevention interventions, and less effective management of chronic conditions, thereby escalating acute care needs and costs [15].

Our third and fourth key findings indicate that unattached individuals with multimorbidity exhibited the highest levels of healthcare utilization and costs among all groups. Similarly, longer durations of unattachment were associated with further increases in healthcare utilization and costs. This trend may be attributed to a shift in healthcare utilization patterns among unattached

individuals, including reliance on episodic care or complete disengagement from the healthcare system. Such shift results in more fragmented, costly healthcare encounters, including increased utilization of walk-in clinics, ED visits, and specialist services, while simultaneously undermining the long-term management of health conditions [8, 15, 30].

Although longer unattachment durations were generally associated with increased healthcare utilization and costs, we observed a tailing-off effect in the very long-term unattached group. This non-linear trend may be attributed to the heterogeneous nature of the unattached population. This group includes individuals who are neither formally enrolled with a PCP nor access any form of primary care, potentially reflecting a healthy non-user bias. This bias is particularly evident in low-comorbidity groups, where unattachment appears to have a seemingly protective effect. Supporting this hypothesis, research from the PUPPY study in Nova Scotia indicates that unattached individuals on a centralized waitlist (i.e., actively seeking care) exhibit higher ED visits and hospitalizations compared to those not on the waitlist [9].

Several other hypotheses may explain this tail-off effect. Beyond the healthy non-user phenomenon, the unattached population may also include individuals with multiple undiagnosed comorbidities who survive for extended periods despite lacking primary care access. This could introduce survivor bias, as those with more severe conditions experience higher mortality rates earlier in the study period, leading to competing risks and their subsequent exclusion from the cohort [11]. Another plausible explanation is "system fatigue", whereby individuals who have unsuccessfully sought primary care for years may eventually disengage from the healthcare system altogether. This aligns with previous research indicating that unattached individuals often express lower confidence in the healthcare system, suggesting a potential interplay between attachment status and healthcare trust [31]. Additionally, financial, logistical, and personal barriers may further deter healthcare engagement among unattached individuals, leading to delayed care-seeking, more severe hospitalizations, and ultimately, higher mortality rates [32].

Our findings indicate that over 20% of Ontario's population falls within the "unattached" or "non-enrolled care" category. While Ontario's Primary Care Action Plan aims to ensure universal primary care attachment through historic investments, significant challenges persist on both the demand and supply sides [33]. Addressing these challenges will require a multifaceted approach, including expanding team-based care models, increasing family medicine residency training spots, leveraging financial incentives, healthcare innovation and streamlining pathways for internationally trained family physicians to practice in Canada [34, 35].

Future directions

Our study identifies distinct patterns of ED and hospital use based on comorbidities, attachment status and unattachment duration. Future work should examine these differences with greater granularity, including the duration, frequency, and complexity of hospitalizations. Further investigation should assess how attachment status and unattachment duration relate to both disease severity and mortality, given the possible presence of survivor bias in our results. This is particularly relevant in light of a recent study from Norway, which found that long-term attached patients have drastically lower odds of mortality (25%) compared to those who were short-term attached [36]. Our study does not provide a comprehensive view of the changes in healthcare utilization among the recently unattached, nor does it capture their evolution and outcomes over time [37, 38]. Further exploration of this area could augment our initial findings. Lastly, we identified that prolonged unattachment leads to increased healthcare utilization. Further examination of this long-term unattached cohort, considering factors such as geographic location, disability, or newcomer status, may inform the design of future primary care policies and interventions to better address barriers to attachment.

Limitations

Our study has several limitations. The observational nature of the data and the brief study window preclude the establishment of causal relationships based solely on our results. The study may be limited by misclassification bias. For example, our approach may have misclassified individuals receiving continuous primary care from fee-for-service physicians. Additionally, we did not include the relatively small number of individuals who receive primary care at Community Health Centres (CHCs) or Nurse Practitioner-Led Clinics (NPLCs), both of which are specific, publicly funded primary care models in Ontario. Currently, there are 75 CHCs and 25 NPLCs in Ontario [39, 40].

Ontario's population is diverse, and stratifying our cohort into three attachment categories may oversimplify underlying differences. For instance, reasons for unattachment likely differ between children (parent-determined) and adults (self-determined), which may influence healthcare utilization patterns. Additionally, while we stratified individuals in the "non-enrolled care" group based on primary care use, we did not apply a similar stratification to formally enrolled individuals. This may have introduced biases, such as healthy non-user bias, affecting comparability across groups.

Our adjusted models accounted for a wide range of covariates, including demographic and patient health characteristics, yet our findings suggest that we may not have fully captured the complex differences between attached and unattached populations. Notably, we did not adjust for continuity of care, which could influence the outcomes and the comparability between groups. Additionally, we used the count of ADGs as both a covariate and a basis for stratifying groups by comorbidity level, a common approach in the literature [41–43]. However, not all ADGs represent the same level of severity or impact, meaning some groups may have had a higher total ADG count driven by certain conditions while lacking others of potentially greater clinical significance. We modeled healthcare utilization outcomes as dichotomous variables in the regression analyses, rather than as continuous measures. This approach facilitates interpretability; however, it may have led to an oversimplification of the findings.

We acknowledge that unattached individuals not accessing any form of primary care are likely to have higher rates of undiagnosed comorbidities, as early detection of certain chronic diseases often necessitates primary care contact, prior to the condition presenting with symptoms or complications that trigger healthcare use leading to the documentation of a formal diagnosis. Lastly, our observation period coincides with the COVID-19 pandemic, which likely influenced attachment dynamics due to widespread disruption in healthcare access, altered care-seeking behaviors, and resource reallocation [44]. The abovementioned factors, along with Canada's universally funded healthcare system, may potentially limit generalizability to other healthcare contexts.

Conclusion

This study suggests that ensuring PCP attachment for patients with multimorbidity may result in substantial reductions in ED and hospital use and total healthcare costs. Our findings highlight disparities in healthcare utilization and costs in Ontario, based on comorbidities, attachment status and unattachment duration. Attached residents with low comorbidities incurred the lowest median 1-year healthcare cost, at $287, while attached individuals with high comorbidities experienced a 1190% increase in costs, reaching a median of $3,711, and long-term unattached residents with high comorbidities had median costs of $8,177. The latter represents a staggering 2849% increase from the lowest bracket. As jurisdictions strive to address primary care shortages, policymakers may consider the findings in this study to balance the immediate chronic disease management needs of individuals with multimorbidity, alongside the potential of primary care to promote health and prevent disease in the future. There is a need to prioritize attachment for individuals who have multiple chronic conditions, while minimizing the level of long-term unattachment.

Abbreviations

ADG	Aggregated Diagnosis Groups
CHC	Community Health Centre
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
DAD	Discharge Abstract Database (ICES)
ED	Emergency department
NACRS	National Ambulatory Care Reporting System database (ICES)
NPLC	Nurse Practitioner-Led Clinic
OHIP	Ontario Health Insurance Plan claims database (ICES)
PCP	Primary care provider
PCPOP	Primary Care Population database (ICES)
RPDB	Registered Persons Database (ICES)

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12875-025-02771-8.

Supplementary Material 1

Acknowledgements

This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health (MOH) and the Ministry of Long-Term Care (MLTC). This document used data adapted from the Statistics Canada Postal Code^{OM} Conversion File, which is based on data licensed from Canada Post Corporation, and/or data adapted from the Ontario Ministry of Health Postal Code Conversion File, which contains data copied under license from ©Canada Post Corporation and Statistics Canada. We thank IQVIA Solutions Canada Inc. for use of their Drug Information File. Parts of this material are based on data and/or information compiled and provided by CIHI, the Ontario Ministry of Health, and Ontario Health (OH). The analyses, conclusions, opinions and statements expressed herein are solely those of the authors and do not reflect those of the funding or data sources; no endorsement is intended or should be inferred.

Author contributions

All authors have contributed sufficiently to meet the criteria for authorship, as per the ICMJE authorship criteria, and have made the following contributions: J.F., S.C., and L.B. contributed to the conception and design of the study. A.G. conducted the acquisition and analysis of data. All authors contributed to the analysis and interpretation of results. J.F., S.C., and A.S. drafted the manuscript, which was critically revised by L.B. All authors read and approved the final manuscript. All authors confirm that they had full access to all the data in the study and accept responsibility to submit for publication.

Funding

This project was funded by the Ontario Ministry of Health via the Innovations Strengthening Primary Health Care through Research (INSPIRE-PHC) Applied Health Research Question (AHRQ) Program. This study was also funded by a grant from the University of Ottawa Department of Family Medicine.

Data availability

The dataset from this study is held securely in coded form at ICES. While legal data sharing agreements between ICES and data providers (e.g., healthcare organizations and government) prohibit ICES from making the dataset publicly available, access may be granted to those who meet pre-specified criteria for confidential access, available at www.ices.on.ca/DAS (email: das@ices.on.ca). The full dataset creation plan and underlying analytic code are available from the authors upon request, understanding that the computer programs may rely upon coding templates or macros that are unique to ICES and are therefore either inaccessible or may require modification.

Declarations

Ethics approval and consent to participate

ICES is a prescribed entity under Ontario's Personal Health Information Protection Act (PHIPA). Section 45 of PHIPA authorizes ICES to collect personal health information, without consent, for the purpose of analysis or compiling statistical information with respect to the management of, evaluation or monitoring of, the allocation of resources to or planning for all or part of the health system. Projects that use data collected by ICES under Sect. 45 of PHIPA, and use no other data, are exempt from REB review. The use of the data in this project is authorized under Sect. 45 and approved by ICES' Privacy and Legal Office. All methods were performed in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

Jonathan Fitzsimon and Lise M. Bjerre are supported by INSPIRE-PHC and ICES, both of which receive funding from grants by the Ontario Ministry of Health. Additionally, they are supported by the University of Ottawa Department of Family Medicine. Jonathan Fitzsimon is the medical lead at the Renfrew County Virtual Triage and Assessment Centre. Shawna Cronin is supported by a post-doctoral fellowship from the Institut du Savoir Montfort. Lise M. Bjerre is further supported by the University of Ottawa and the Institut du Savoir Montfort Chair in Family Medicine. She reports receiving research funding from the Canadian Institute of Health Research. Anastasia Gayowsky is supported as a data analyst at ICES. Antoine St-Amant is supported as a research coordinator by the Institut du Savoir Montfort. No other competing interests are declared.

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Received: 5 September 2024 / Accepted: 24 February 2025
Published online: 17 March 2025

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