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Higher Post-Acute Health Care Costs Following SARS-CoV-2 Infection Among Adults in Ontario, Canada

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Purpose and Introduction: Growing evidence suggests SARS-CoV-2 infection increases the risk of long term cardiovascular, neurological, and other effects. However, post-acute health care costs following SARS-CoV-2 infection are not known.

Patients and Statistical Methods: Beginning 56 days following SARS-CoV-2 polymerase chain reaction (PCR) testing, we compared person-specific total and component health care costs (2020 CAD$) for the first year of follow-up at the mean and 99th percentiles of health care costs for matched test-positive and test-negative adults in Ontario, Canada, between January 1, 2020, and March 31, 2021. Matching included demographics, baseline clinical characteristics, and two-week time blocks.

Results: For 531,182 people, mean person-specific total health care costs were $513.83 (95% CI $387.37-$638.40) higher for test-positive females and $459.10 (95% CI $304.60-$615.32) higher for test-positive males, which were driven by hospitalization, long-term care, and complex continuing care costs. At the 99th percentile of each subgroup, person-specific health care costs were $12,533.00 (95% CI $9008.50-$16,473.00) higher for test-positive females and $14,604.00 (95% CI $9565.50-$19,506.50) for test-positive males, driven by hospitalization, specialist (males), and homecare costs (females). Cancer costs were lower. Six-month and 1-year cost differences were similar.

Conclusion: Post-acute health care costs after a positive SARS-CoV-2 PCR test were significantly higher than matched test-negative individuals, and these increased costs persisted for at least one year. The largest increases health care costs came from hospitalizations, long-term care, complex continuing care, followed by outpatient specialists (for males) and homecare costs (for women). Given the magnitude of ongoing viral spread, policymakers, clinicians, and patients should be aware of higher post-acute health care costs following SARS-CoV-2 infection.

Plain Language Summary: We examined differences in health care costs for people who had a positive PCR for SARS-CoV-2 in Ontario, Canada, starting 56 days after the positive test at looking forward at least 1 year, matched by >20 characteristics to people with a negative PCR within two weeks. During the study, the average health care costs per person were approximately $4800 (2020 CAD$). We found that on average, health care costs were $513.83 higher (2020 CAD$; +11% higher than average health care costs) for women who had a positive PCR test and $459.10 higher (+10% higher than average health care costs) for men who had a positive PCR test. Most of the increased costs were due to hospitalization, long-term care, and complex continuing care costs.

When we looked at people who had the highest health care costs (the 99th percentile), health care costs for women with a positive PCR test were $12,533.00 higher (+261% higher than average health care costs) and $14,604.00 higher for men (+304% higher than average health care costs), with higher costs driven by hospitalization, specialist (males), and homecare costs (females). Cancer costs were lower for people with a positive test. In summary, post-acute health care costs were higher for people who had a positive SARS-CoV-2 PCR test, after accounting for multiple patient-level factors. Higher costs persisted for a least one year of follow-up.

Keywords: long COVID, health policy, sex differences

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Introduction

COVID-19 and its downstream effects are among the most pressing challenges to the long-term health and health care systems worldwide,[1,2] with over half of adults in Canada infected by fall of 2022.[3–5] Given on-going, widespread transmission of this airborne pathogen, there is growing recognition of considerable health impacts beyond the acute phase of COVID-19.[6] This includes metabolic derangements, autoimmune conditions, and cardiovascular disease among others, occurring across the spectrums of age and severity of acute infection.[7–12]

Health care use during the acute phase of SARS-CoV-2 infection is higher than otherwise similar, uninfected individuals due largely to hospitalizations, although clinic visits, diagnostics and medications also contribute.[13,14] Differences in post-acute (ie, delayed), direct health care costs after infection are, however, not well understood. Most people are expected to be experience at least one SARS-CoV-2 infection per year; thus, even small, sustained increases in health care costs after infection could impose significant strain on health care systems. Policy makers need detailed understanding of delayed health care burdens after SARS-CoV-2 infection so they can make informed policy decisions, and clinicians and patients need this information so they can weigh individual risks of infection.

The goal of this study was to test the hypothesis that health care costs were higher after the acute phase of SARS-CoV-2 infection, compared to otherwise similar adults who were not infected. We therefore compared total and component health care costs of community-dwelling adults in Ontario, Canada starting ≥56 days following a positive SARS-CoV-2 polymerase chain reaction (PCR) to matched individuals who tested negative for SARS-CoV-2.

Material and Methods

Study Design

This retrospective cohort was constructed using population-level administrative and health care data linked and held at ICES, formerly known as the Institute for Clinical Evaluative Sciences. In accordance with Ontario's Personal Health Information Protection Act (section 45), which permits collection and analysis of health care and demographic data for health system evaluation, individual consent was not obtained.[15] ICES maintains and complies with rigorous security and quality control measures to ensure data privacy and accuracy. This study was conducted in accordance with the Declaration of Helsinki.

Cohort Construction and Matching

All community-dwelling adults (≥18 years of age) in Ontario, Canada with sufficient demographic information for data linkage (valid date of birth, sex, and death information) who underwent PCR testing for SARS-CoV-2 between January 1, 2020 and March 31, 2021 and were alive eight weeks (56 days) after the date of PCR test were eligible. Datasets used for cohort construction and variable definitions are listed in Supplementary Tables E1 and E2, respectively. At the time of the study, PCR testing was widely available and funded by the public health care system. Vaccination began in December of 2020, and by May of 2021 more than half of people in Ontario had received at least one COVID-19 vaccine dose.

The index date was defined as the date of first positive outpatient SARS-CoV-2 PCR test or, for individuals with only negative PCR test(s), the last test date. PCR results reported as pending or indeterminate (<0.02%) were excluded.

Individuals with a positive SARS-CoV-2 PCR test result were matched to those with only negative test results by 2-week pandemic periods, public health unit, vaccination status, and a propensity score computed from a large set of demographic, clinical, and health services factors, including component health care costs in year prior to the index PCR date (for details, see Supplementary Table E2).[16] Subjects were matched on the logit of the propensity score using a caliper width equal to 0.05 times the standard deviation of the propensity score,[17] and standardized difference <0.1 was considered as indicative of good balance between exposure groups.[16,18]

Outcome: Health Care Costs

Because symptoms of acute SARS-CoV-2 infection generally resolve within eight weeks,[19–22] follow-up to assess post-acute health care costs began eight weeks (56 days) after the index date and ended on May 26, 2022, or death, whichever occurred first. The primary outcome was cost differences over the first year of follow-up for test-positive versus test-negative individuals, compared at the mean, median, 95th percentile, and 99th percentiles of component health care costs.

We examined costs across their distribution because health care costs are highly skewed, with a small proportion of high costs.[23] Note that mean costs are additive, but this is not the case for median, 95th percentile, or 99th percentile costs. Total person-specific costs of health care (ie, the amount of money spent by the Ontario Ministries of Health and Long Term Care) was comprised of 11 mutually exclusive component costs for the period starting 56 days after the index PCR test date (see Supplementary Table E1).[24,25] Component costs were summed and divided by the number of days of follow-up (ie, exposure time), multiplied by 365 days to calculate annual per-person costs, and standardized to the Canadian dollar in 2020 (2020 CAD$). Only hospital-based costs that occurred during follow-up were included.

Secondary outcomes included the following dichotomous outcomes for outpatient cancer, rehabilitation, home care, mental health admission, complex continuing care, and long-term care costs, overall and stratified by sex: 1) being a high-cost health care user, defined as >95th percentile of total health care costs from the matched cohort,[24,25] and 2) any reported post-acute health care cost.

Statistical Analyses

Baseline characteristics of the unmatched and matched cohorts were reported as means with standard deviations (SD), medians and interquartile ranges (IQR), or frequencies, as appropriate. Total and component annualized health care costs based on 1-year and 6-month follow-up were reported as means (SDs) and medians (Q1, Q3).

Analyses were performed for the overall cohort and stratified by sex based on prior work[14,26,27] and evidence of interaction with some component costs (Supplementary Table E3; P-value threshold <0.10). To compare health care costs across a right-skewed distribution, person-specific annualized costs for matched test-positive versus negative individuals were compared at the mean (by paired *T*-test), median, 95th percentile, and 99th percentile (by Wilcoxon signed rank test),[28] and 95% CI's were generated by bootstrapping with 2000 bootstrap replicates.[29] Sensitivity analyses censored at admission to long-term care and six months. Relative risks (RR) were computed for 6-month and 1-year high-cost health care use and any post-acute health care for six component costs (outpatient cancer care, rehabilitation, home care, mental health hospitalization, complex continuing care, and long-term care). The 95% CI RR were estimated using methods appropriate for matched data.[30] All analyses were performed in SAS v. 9.04.

Results

Between January 1, 2020, and March 31, 2021, there were >11 million SARS-CoV-2 PCR tests completed for 3,777,451 unique adults. Of the 3,631,040 individuals in the unmatched cohort (Supplementary Table E4), 268,521 (7.4%) had a positive SARS-CoV-2 PCR test, 99% of whom were successfully matched to a test-negative person. The resulting matched cohort consisted of 531,182 individuals (Supplementary Figure E1 and Table 1). Compared to the unmatched cohort, the matched cohort was slightly younger and had higher proportion of males, urban, lower income, ethnically diverse neighborhoods with overall slightly lower prevalence of comorbid conditions and lower baseline health care costs. In addition, individuals in the matched cohort were less likely to have received any COVID vaccine dose, and they more often underwent PCR testing during late 2020 or early 2021 compared to the unmatched cohort.

Total Person-Specific Annualized Health Care Cost Differences

Differences in annual total and component health care costs per person, overall and stratified by sex, comparing matched test-positive and test-negative people are shown in Figure 1 (mean cost differences) and Figure 2 (99th percentile cost differences). Median and 95th percentiles cost differences are found in Supplementary Figures E2 and E3, respectively. Mean person-specific total health care costs in the first year of follow-up were $487.08 (95% CI $393.69, $593.28) higher for test-positive compared to test-negative matched individuals. For test-positive females, mean person-specific total health care costs were $513.83 (95% CI $387.37, $638.40) higher, and $459.10 (95% CI $304.60, $615.32) higher for test-positive males. At the 99th percentile, test-positive individuals had $13,306.00 (95% CI, $10,004.00, $16,965.50) greater annual total health care costs compared to test-negative people, with an increase of $12,533.00 (95% CI % $9008.50, $16,473.00) for test-positive females, and $14,604.00 (95% CI $9565.50, $19,506.50) for test-positive males.

Table 1 Baseline Demographics and Clinical Characteristics of the Matched Cohort and Characteristics Used for Matching*

		Test Negative N=265,591	Test Positive N=265,591	Standardized Difference
Age (years)	Mean (SD)	44.11 (17.16)	44.18 (17.17)	0.004
	Median (Q1-Q3)	43 (29–56)	43 (29–56)	0.004
Female	n (%)	134,105 (50.5%)	134,105 (50.5%)	0
Rural	n (%)	9,703 (3.7%)	9,532 (3.6%)	0.003
Johns Hopkins Frailty Score	n (%)	7,688 (2.9%)	7,636 (2.9%)	0.001
Recent flu vaccination	n (%)	65,638 (24.7%)	65,885 (24.8%)	0.002
Hypertension	n (%)	60,493 (22.8%)	60,919 (22.9%)	0.004
Diabetes	n (%)	36,510 (13.7%)	37,104 (14.0%)	0.006
Emphysema	n (%)	4,043 (1.5%)	4,053 (1.5%)	0
Heart failure	n (%)	4,875 (1.8%)	4,898 (1.8%)	0.001
Dementia	n (%)	3,143 (1.2%)	3,193 (1.2%)	0.002
Asthma	n (%)	28,040 (10.6%)	27,940 (10.5%)	0.001
Cancer	n (%)	4,885 (1.8%)	4,730 (1.8%)	0.004
Surgery in previous 6 weeks	n (%)	2,251 (0.8%)	2,175 (0.8%)	0.003
Ischemic stroke	n (%)	2,524 (1.0%)	2,508 (0.9%)	0.001
Hemorrhagic stroke	n (%)	261 (0.1%)	220 (0.1%)	0.005
Valvular disease	n (%)	234 (0.1%)	232 (0.1%)	0
Atrial fibrillation	n (%)	4,894 (1.8%)	4,815 (1.8%)	0.002
Acute myocardial infarction	n (%)	1,750 (0.7%)	1,758 (0.7%)	0
Percutaneous coronary intervention	n (%)	2,124 (0.8%)	2,186 (0.8%)	0.003
Coronary artery bypass graft	n (%)	641 (0.2%)	639 (0.2%)	0
Ischemic heart disease	n (%)	9,755 (3.7%)	9,708 (3.7%)	0.001
Major bleeding	n (%)	2,115 (0.8%)	2,098 (0.8%)	0.001
Renal disease	n (%)	2,630 (1.0%)	2,711 (1.0%)	0.003
Pneumonia	n (%)	19,479 (7.3%)	19,748 (7.4%)	0.004
Alcohol use disorder	n (%)	1,527 (0.6%)	1,529 (0.6%)	0
Venous thromboembolism	n (%)	24,096 (9.1%)	23,731 (8.9%)	0.005
Income Quintile 1	n (%)	66,141 (24.9%)	65,495 (24.7%)	0.006
Income Quintile 2	n (%)	57,647 (21.7%)	57,816 (21.8%)	0.002
Income Quintile 3	n (%)	56,861 (21.4%)	56,985 (21.5%)	0.001
Income Quintile 4	n (%)	46,659 (17.6%)	47,195 (17.8%)	0.005
Income Quintile 5	n (%)	38,283 (14.4%)	38,100 (14.3%)	0.002
Instability Quintile 1 (Least unstable)	n (%)	71,842 (27.0%)	72,103 (27.1%)	0.002
Instability Quintile 2	n (%)	44,802 (16.9%)	44,443 (16.7%)	0.004
Instability Quintile 3	n (%)	40,966 (15.4%)	40,637 (15.3%)	0.003
Instability Quintile 4	n (%)	43,344 (16.3%)	43,544 (16.4%)	0.002
Instability Quintile 5 (Most unstable)	n (%)	64,637 (24.3%)	64,864 (24.4%)	0.002
Deprivation Quintile 1 (Least deprived)	n (%)	44,432 (16.7%)	45,003 (16.9%)	0.006
Deprivation Quintile 2	n (%)	47,436 (17.9%)	47,516 (17.9%)	0.001
Deprivation Quintile 3	n (%)	52,444 (19.7%)	52,391 (19.7%)	0.001
Deprivation Quintile 4	n (%)	55,585 (20.9%)	55,454 (20.9%)	0.001
Deprivation Quintile 5 (Most deprived)	n (%)	65,694 (24.7%)	65,227 (24.6%)	0.004
Dependency Quintile 1 (Least dependent)	n (%)	91,415 (34.4%)	91,625 (34.5%)	0.002
Dependency Quintile 2	n (%)	59,585 (22.4%)	59,763 (22.5%)	0.002
Dependency Quintile 3	n (%)	43,941 (16.5%)	44,105 (16.6%)	0.002
Dependency Quintile 4	n (%)	37,817 (14.2%)	37,392 (14.1%)	0.005
Dependency Quintile 5 (Most dependent)	n (%)	32,833 (12.4%)	32,706 (12.3%)	0.001
Ethnic Concentration Quintile 1 (Least)	n (%)	17,661 (6.6%)	17,161 (6.5%)	0.008
Ethnic Concentration Quintile 2	n (%)	24,946 (9.4%)	24,809 (9.3%)	0.002
Ethnic Concentration Quintile 3	n (%)	34,340 (12.9%)	35,039 (13.2%)	0.008
Ethnic Concentration Quintile 4	n (%)	56,073 (21.1%)	56,934 (21.4%)	0.008
Ethnic Concentration Quintile 5 (Most)	n (%)	132,571 (49.9%)	131,648 (49.6%)	0.007
≥2 COVID vaccine doses	n (%)	289 (0.1%)	289 (0.1%)	0
1–2 COVID vaccine doses	n (%)	1,321 (0.5%)	1,321 (0.5%)	0

(*Continued*)

Table 1 (Continued).

		Test Negative N=265,591	Test Positive N=265,591	Standardized Difference
0 COVID vaccine doses	n (%)	263,981 (99.4%)	263,981 (99.4%)	0
Prior mental health hospitalization	n (%)	4,369 (1.6%)	4,272 (1.6%)	0.003
Prior emergency department visit for mental health condition	n (%)	11,135 (4.2%)	11,069 (4.2%)	0.001
Prior outpatient mental health visit	n (%)	48,100 (18.1%)	47,992 (18.1%)	0.001
1-year Baseline hospital-based costs	Mean (SD)	1305.54 (10,282.53)	1241.99 (9505.14)	0.006
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.046
1-year Baseline emergency department costs	Mean (SD)	241.64 (806.06)	235.37 (977.53)	0.007
	Median (Q1-Q3)	0 (0–145)	0 (0–137)	0.009
1-yr Baseline medication costs	Mean (SD)	445.92 (3665.39)	448.99 (2849.61)	0.001
	Median (Q1-Q3)	0 (0–19)	0 (0–14)	0.022
1-yr Baseline outpatient-specialist costs	Mean (SD)	668.03 (3554.04)	664.41 (4084.39)	0.001
	Median (Q1-Q3)	83 (0–486)	80 (0–455)	0.023
1-yr Baseline outpatient-cancer costs	Mean (SD)	141.74 (2871.91)	133.94 (3052.78)	0.003
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.016
1-yr Baseline outpatient-primary care costs	Mean (SD)	331.42 (657.48)	331.64 (660.98)	0
	Median (Q1-Q3)	222 (102–377)	222 (99–384)	0.002
1-yr Baseline outpatient-lab costs	Mean (SD)	50.46 (88.58)	50.50 (85.67)	0
	Median (Q1-Q3)	19 (0–68)	21 (0–70)	0.024
1-yr Baseline rehabilitation costs	Mean (SD)	88.18 (1902.80)	82.94 (1754.76)	0.003
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.005
1-yr Baseline homecare costs	Mean (SD)	215.08 (2503.13)	218.73 (2268.92)	0.002
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.004
1-yr Baseline Mental health admission costs	Mean (SD)	150.24 (4896.44)	157.81 (5659.92)	0.001
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.019
1-yr Baseline complex and continuing care costs	Mean (SD)	123.31 (4234.60)	122.23 (3879.81)	0
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.004
1-yr Baseline long-term care costs	Mean (SD)	0.02 (4.14)	0.02 (5.50)	0.001
	Median (Q1-Q3)	0 (0–0)	0 (0–0)	0.002

Notes: *Also matched by 2-week period of testing, public health unit, and Johns Hopkins ACG © diagnosis group categories 1–12.

Component Person-Specific Annualized Health Care Cost Differences

The largest differences in mean component costs in the first year of follow-up for test-positive individuals were for hospital-based care ($244.83, 95% CI $188.59, $301.22), long-term care ($102.16, 95% CI $90.09, $113.89), and complex continuing care ($79.28, 95% CI $49.98, $107.96). There were smaller but significantly higher costs for outpatient specialist, rehabilitation, emergency department, outpatient primary care (for females only, with no detected difference for males), and outpatient laboratory costs, and overall no detected differences in outpatient medication, mental health admission costs (no difference for males; decreased costs for test-positive females), or homecare (increased for females, no difference for males). Mean person-specific outpatient cancer care costs were lower (-$75.89, 95% CI -$96.71, -$54.45) for test-positive individuals.

At the 99th percentile, the largest cost differences for test-positive versus test-negative people were hospital-based care ($6035.00, 95% CI $4647.50, $7402.50) homecare ($937.00, 95% CI $389.50, $1508.00; higher only for females), and outpatient specialist care ($407.00, 95% CI $177.00, $731.00; higher only for males). ED costs were $170.00 (95% CI $96.00, $241.00) higher for test-positive individuals, while there were no differences in costs for outpatient primary care, medications, or laboratory tests, and zero costs for mental health admission, complex continuing care, or long-term care. Outpatient cancer care costs were lower over the first year of follow-up, -$521 (95% CI -$708.50, -$399.00) overall, but test-positive females had -$844.00, (95% CI -$1462.50, -$415.00) lower outpatient cancer care costs, with no detected difference for males.

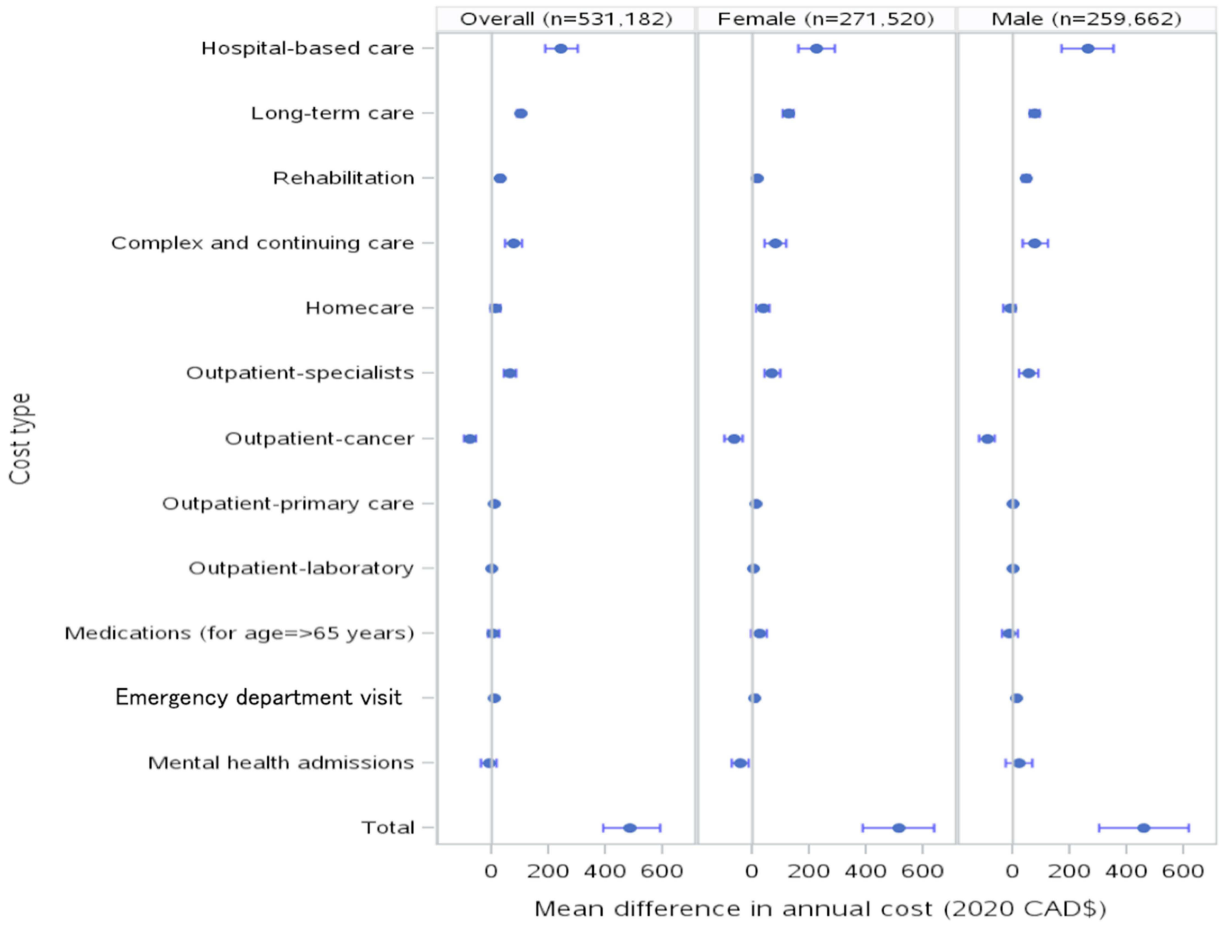

Figure 1 Differences in person-specific annual mean health care costs* for test-positive versus test-negative matched individuals, overall and by sex (95% confidence intervals in 2020 CAD$; starting 56 days after polymerase chain reaction test).
Notes: $0 to +$600 range. * By paired *T*-test.

Sensitivity Analyses

Censoring at entrance to long-term care produced similar results (Supplementary Figure E4), with slightly smaller outpatient primary care and hospitalization cost differences than in primary analyses. Annualized 6-month cost differences, overall and stratified by sex, (Supplementary Figure E5) were also similar, with some exceptions by sex, component cost, and distribution. RR's for being a high-cost user generally decreased over time (Table 2 and Supplementaty Table E5 for risk differences), although women continued to have elevated risk for at 1-year for being a high-cost user of multiple types of high-intensity health care resources compared to matched, test-negative women. RR for any care also generally decreased over time, with differences by sex.

Discussion

Among 531,182 matched adults, post-acute (≥56 days after PCR testing) person-specific, annualized health care costs in the first year of follow-up were on average $487 higher ($513 for females, $459 for males) for individuals who had a positive SARS-CoV-2 PCR test compared to matched, test-negative individuals. Cost differences at the 99th percentile over the first year of follow-up were $13,306 higher ($12,533 for females, $14,604 for males) for test-positive individuals. With annual mean health care expenditures of $4800 per-person in Ontario for 2020,[31] this >10% increase in mean health care costs over the first year of post-acute follow-up does not account for costs that may extend beyond a year of follow-up or for potential rising costs with re-infections.[2] Cost differences did not returned to baseline over the first year of post-acute follow-up.

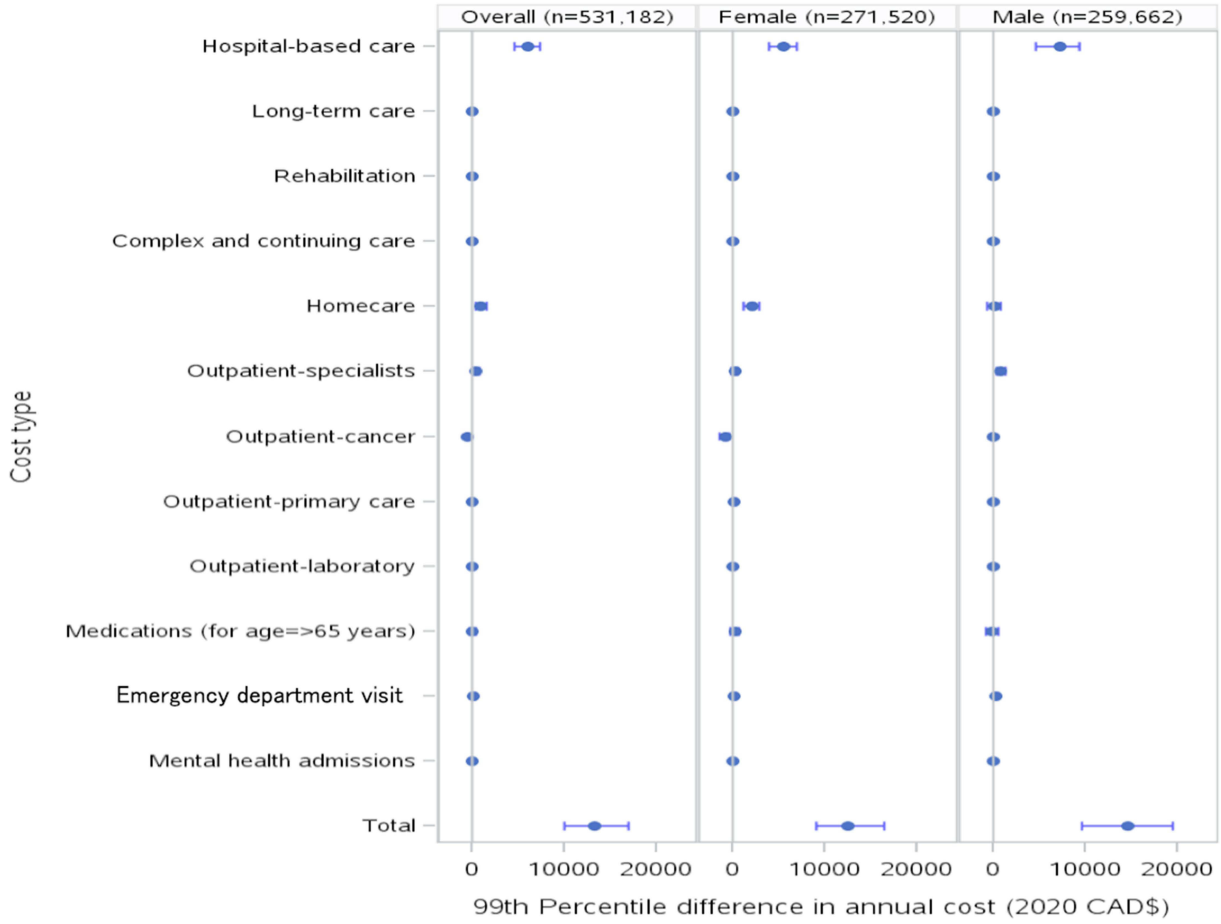

Figure 2 Differences in person-specific annual 99th percentile health care costs* for test-positive versus test-negative matched individuals, overall and by sex (95% confidence intervals in 2020 CAD$; starting 56 days after polymerase chain reaction test).
Note: $1000 to +$20,000 range. * By paired *T*-test.

While hospital costs were the main driver of total cost, important costs were also incurred by long-term and complex continuing care, as well as homecare (for females), outpatient specialist (for males), and emergency department costs. Although mean cost differences for primary care and emergency department ($9.27 and $12.14, respectively) were relatively small, any sustained increase demand for these scarce resources has the potential for clinically important consequences in an already strained health care system.[32–34]

Notably, outpatient mean cancer care costs were lower for test-positive individuals, particularly for females, who were also less likely to have any outpatient cancer care costs but had increased risk of being a high-cost outpatient cancer care user over the first year of follow-up. Taken together, this raises the possibility that cancer diagnosis and/or treatment may have been impacted by SARS-CoV-2 infection, its complications, or changes in the health system.[35]

Post-acute symptoms and complications of SARS-CoV-2 infection are common and can be persistent.[2,36–42] An estimated 10% of people meet criteria for long COVID following SARS-CoV-2 infection, with incidence and prevalence varying by case definition, outcome measures, pandemic phase, vaccination status, and follow-up duration.[43–45] Vaccination in Ontario was administered entirely through the public health care system, with widespread, free access to vaccine clinics and strategic vaccination outreach programs; SARS-CoV-2 vaccination was required through March 1, 2022. Several previous studies addressing post-acute COVID-19 health care costs revealed higher hospital costs, as well as higher mortality and overall health care utilization.[46–48] However, these studies were limited to 6-month follow-up of populations covered by specific health insurance programs early in the pandemic, used diagnosis codes to identify COVID-19 cases, were conducted in the US, which has the highest health care costs in the world, and they did not include home-based or other complex, long-term medical care not covered by health insurance in the US.

Table 2 Relative Risks* Comparing Test-Positive versus Test-Negative People, Overall and by Sex, for: (A) Being a High-Cost Health Care User (>95th Percentile) Within 6 Months and 1 Year of Follow-Up, and (B) Any Post-Acute Health Care Cost (>$0) Within 6 Months and 1 Year of Follow-Up

	Outcome	6-months			1-year		
		RR	RR Lower 95% CI	RR Upper 95% CI	RR	RR Lower 95% CI	RR Upper 95% CI
(A) High-Cost Defined as Cost>95th Percentile							
Overall (n=265,591)	Outpatient cancer	1.11	1.09	1.14	1.05	1.03	1.08
	Rehabilitation	1.13	1.10	1.16	1.05	1.02	1.07
	Home care	1.07	1.05	1.10	1.02	1.00	1.04
	Mental health hospitalization	1.13	1.10	1.15	1.04	1.02	1.06
	Complex continuing care	1.18	1.16	1.21	1.11	1.09	1.14
	Long-term care	1.07	1.04	1.09	1.05	1.02	1.07
Female (n=135,760)	Outpatient cancer	1.15	1.12	1.19	1.09	1.05	1.12
	Rehabilitation	1.18	1.14	1.21	1.09	1.05	1.12
	Home care	1.08	1.04	1.11	1.02	0.99	1.06
	Mental health hospitalization	1.15	1.12	1.19	1.04	1.01	1.07
	Complex continuing care	1.19	1.16	1.23	1.12	1.09	1.16
	Long-term care	1.09	1.05	1.12	1.07	1.04	1.10
Male (n=129,831)	Outpatient cancer	1.07	1.04	1.11	1.02	0.99	1.05
	Rehabilitation	1.07	1.03	1.11	1.00	0.96	1.03
	Home care	1.07	1.03	1.10	1.01	0.98	1.05
	Mental health hospitalization	1.10	1.06	1.14	1.04	1.00	1.08
	Complex continuing care	1.17	1.13	1.21	1.10	1.06	1.14
	Long-term care	1.03	0.99	1.07	1.01	0.97	1.05
(B) Any Post-Acute Health Care Cost							
Overall (n=265,591)	Outpatient cancer	0.73	0.69	0.78	0.79	0.75	0.83
	Rehabilitation	2.42	2.12	2.76	1.67	1.51	1.86
	Home care	1.10	1.07	1.13	1.06	1.04	1.09
	Mental health hospitalization	0.97	0.88	1.08	0.89	0.82	0.97
	Complex continuing care	2.05	1.86	2.27	1.68	1.54	1.83
	Long-term care	2.46	2.20	2.75	2.04	1.86	2.23
Female (n=135,760)	Outpatient cancer	0.76	0.70	0.82	0.82	0.77	0.88
	Rehabilitation	2.21	1.81	2.71	1.44	1.24	1.68
	Home care	1.13	1.09	1.17	1.09	1.06	1.13
	Mental health hospitalization	0.89	0.76	1.04	0.84	0.74	0.95
	Complex continuing care	2.19	1.89	2.53	1.82	1.60	2.06
	Long-term care	2.71	2.33	3.16	2.18	1.92	2.46
Male (n=129,831)	Outpatient cancer	0.70	0.63	0.77	0.75	0.69	0.81
	Rehabilitation	2.58	2.16	3.07	1.90	1.65	2.19
	Home care	1.06	1.02	1.10	1.03	0.99	1.06
	Mental health hospitalization	1.05	0.91	1.20	0.94	0.84	1.06
	Complex continuing care	1.94	1.69	2.23	1.55	1.38	1.75
	Long-term care	2.18	1.85	2.57	1.87	1.63	2.15

Note: *McNemar test.

Our population-level data for a large, universal health care system reduces the risk of selection bias, differential follow-up, and recall bias. In Ontario, all hospitalizations and physician charges are funded by the public health care system. We were also able to examine outpatient costs for primary care, specialist, and cancer care separately. Use of PCR to identify cases likely biases our results towards the null by underestimating true burden infection,[49,50] but we chose a highly specific case definition in order to fully examine post-acute health care costs with less risk of erroneously classifying people as having had SARS-

CoV-2 infection. Our findings may further have been biased towards the null by likely overrepresentation of ill people in the test-negative population, eg, patients undergoing repeated PCR testing for chemotherapy, dialysis, etc.

We also add to existing literature regarding sex differences in COVID-19[51–58] by identifying sex differences for component health care costs. Test-positive males had higher mean cost differences for rehabilitation and mental health care, while test-positive women had higher mean cost differences for outpatient medications, primary care, homecare, and long-term care. Further work is needed to examine the interplay between social factors (eg, caregiver availability for men versus women) and biological factors in order to appropriate plan for and allocate long COVID resources.

With few protective measures in place to prevent ongoing airborne spread and many people therefore expected to contract one or more SARS-CoV-2 infection annually,[2] sustained health care cost increases of the magnitude we describe will require significant health care system restructuring, innovation, and investment of resources, particularly given existing prolonged wait times to access care, insufficient supply of acute and long-term care beds, and projected loss of health care workers.[59–67] Health care workers appear to have higher risk of infection and developing post-acute complications, with 18% unable to return to pre-infection clinical workloads, including nearly half of whom were infected after been fully vaccinated.[68–70] Further, our findings do not account for costs related to disability, unemployment, or reduced quality of life after acute COVID-19, which has been reported to be comparable to that of stage 4 lung cancer.[68,71–75] Implementing protections and other measures to prepare for post-acute complications of SARS-CoV-2 infection could forestall considerable, avoidable health care and other costs.[76]

Limitations

Our findings may not generalize to people without similar access to medical care, who did not seek care, or who sought care outside the traditional health system. We could not adjust body mass index or symptoms severity and duration. However, control individuals may also not have had symptoms, and important post-acute complications occur following mild or asymptomatic acute infections.[77] While this study was conducted prior to more recent variants, growing evidence indicates subsequent strains were not less severe, protection against post-acute complications from vaccination or previous infection wanes rapidly.[78,79] New strains are so immune evasive that prior vaccination and/or infection have been deemed insufficient protection to recent strains, and a minimum of broad age-based annual vaccination is recommended.[80] To date, there is no evidence to that longer-term complications of SARS-CoV-2 infection are completely prevented by vaccination or prior infection, and while vaccination may reduce risks, the duration of that protection is not yet known.[81]

Conclusion

Post-acute health care costs after a positive SARS-CoV-2 PCR test were significantly higher than matched test-negative individuals, and these increased costs persisted for at least one year. The largest increases health care costs came from hospitalizations, long-term care, complex continuing care, followed by outpatient specialists (for males) and homecare costs (for women). Policy makers should plan for sustained increases in health care costs for people infected with SARS-CoV-2. Clinicians and patients should be aware that health care costs may not return to normal within a year of infection. Future work should include cost effectiveness for strategies to prevent infections and treatment of long-term health impacts of SARS-CoV-2 infection.

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This paper has been uploaded to Research Square as a preprint: https://www.medrxiv.org/content/10.1101/2023.08.02.23293563v1

Disclosure

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