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## Age differences in the association between loneliness and anxiety symptoms during the COVID-19 pandemic

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### ABSTRACT

Loneliness and associated mental health problems are of particular concern during the COVID-19 pandemic due to physical distancing and lockdown restrictions. Loneliness is most common among young adults and women during the pandemic, but it is unclear if the association between loneliness and mental health problems, notably anxiety, is strongest in these groups. The objective of this study was to examine whether the association between loneliness and anxiety differed by age and/or gender during the pandemic. We analyzed data from a multi-wave national online survey of Canadians aged 18+ years from May 2020 to March 2021 ( $n = 7,021$ ). Multivariable modified least-squares regression was used to examine whether the association between loneliness and moderate to severe anxiety symptoms (GAD-7 10+) differed by age and/or gender on the additive scale, controlling for socio-demographic factors, depression, hopefulness, and survey wave. Age significantly moderated the association between loneliness and anxiety symptoms while gender did not. Loneliness was associated with anxiety symptoms for all age groups, but the association was not as strong among those aged 70+ years compared to other age groups. Evidence-based loneliness interventions that target younger adults are needed to mitigate the mental health effects of infectious disease events such as COVID-19.

### 1. Introduction

Loneliness – defined as a perceived discrepancy between actual and desired levels of social relationships (Lim et al., 2020) – is a major public health concern during the COVID-19 pandemic. At the outset of the pandemic, loneliness was already recognized as an epidemic in the health literature (Cacioppo and Cacioppo, 2018; Fried et al., 2020; Jeste et al., 2020; The Lancet, 2020). Many studies identified loneliness as a risk factor for mental health problems, cognitive decline, physical morbidities, and premature mortality (Beutel et al., 2017; Cacioppo et al., 2010; Domènech-Abella et al., 2019; Hawkey and Cacioppo,

2010; Meltzer et al., 2013). Loneliness and mental health problems associated with loneliness are of particular concern during the COVID-19 pandemic due to physical distancing and lockdown restrictions requiring people to stay at home and minimize contact with others. Numerous studies have justified this concern, reporting increases in loneliness, anxiety, and other mental health problems during the pandemic (Bu et al., 2020; Czeisler et al., 2021; Li and Wang, 2020; McGinty et al., 2020; Pan et al., 2021; Pierce et al., 2020; Twenge and Joiner, 2020; Varga et al., 2021). Left unaddressed, pandemic loneliness could contribute to long-term increases in chronic mental health problems at the population level.

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Research suggests that young adults and women have been most likely to experience loneliness and mental health problems – notably anxiety – during the COVID-19 pandemic (González-Sanguino et al., 2021; Groarke et al., 2020; Losada-Baltar et al., 2021; Pierce et al., 2020; Turna et al., 2021; Varga et al., 2021; Wang et al., 2020; Wickens et al., 2021). Women may be more likely than men to experience loneliness and anxiety because they typically depend more on social supports and mental health services to cope with psychological distress, which have become more difficult to access due to pandemic restrictions (Pattyn et al., 2015; Ptacek et al., 1994; Wickens et al., 2021). Meanwhile, young adults typically derive satisfaction from social relationships based on the size of their social network and the quantity of social contacts, whereas older adults place more value on the quality of their relationships and social interactions (Nicolaisen and Thorsen, 2017; Wickens et al., 2021). With physical distancing and lockdown restrictions, it may be easier for older adults to maintain a few high-quality social connections compared to younger adults maintaining large social networks. Moreover, older adults have more experience being socially isolated from before the pandemic as well as more effective emotional regulation to buffer against pandemic stressors (Losada-Baltar et al., 2021; Wickens et al., 2021).

Longitudinal research prior to the pandemic suggests that a bidirectional relationship exists between loneliness and anxiety, but with a stronger association with loneliness as the predictor (Domènech-Abella et al., 2019; Santini et al., 2020). Given this bidirectional relationship, and that young adults and women have been most likely to experience loneliness and anxiety, it might be inferred that the association between loneliness and anxiety would be strongest among young adults and women; however, to our knowledge, no study has explored both age and gender differences in the association between loneliness and anxiety during the COVID-19 pandemic. This is a significant gap that limits the ability of policymakers to develop targeted interventions for those at highest risk of mental health problems associated with loneliness. The objective of this study was thus to examine, cross-sectionally, the association between loneliness and anxiety during the COVID-19 pandemic in the general population and explore age and gender differences in this association.

## 2. Methods

### 2.1. Sample

This cross-sectional study is based on publicly available survey data, which were collected by the center for Addiction and Mental Health in collaboration with the survey firm Delvinia (Centre for Addiction and Mental Health, 2020). Data were from seven waves of a national online survey of English-speaking Canadian adults aged 18 years and older who were members of the AskingCanadians web panel. The first six waves were conducted in 2020 from May 8 to May 12 (Wave 1), May 28 to June 1 (Wave 2), June 19 to 23 (Wave 3), July 10 to 14 (Wave 4), September 18 to 22 (Wave 5), and November 27 to December 1, 2020 (Wave 6). Wave 7 was conducted from March 19 to 23, 2021. Quota sampling by age, gender, and region proportional to the English-speaking Canadian population was used. In total, the seven waves had 1005, 1002, 1005, 1003, 1003, 1003, and 1000 respondents respectively, contributing to a pooled sample size of  $n = 7021$ . Participants were not allowed to respond to more than one survey wave; therefore, the pooled sample size represents 7021 distinct individuals. The overall response rate for the 7 waves was 16.1%. Members of the AskingCanadians panel were initially recruited through loyalty partnerships with major Canadian corporations such as department stores, airlines, and retailers. All respondents provided informed consent and received loyalty points for their time and participation in the study. The center for Addiction and Mental Health's Research Ethics Board approved survey data collection.

### 2.2. Outcome measure

Anxiety was measured with the Generalized Anxiety Disorder-7 (GAD-7) questionnaire (Spitzer et al., 2006). The GAD-7 is a widely used tool in mental health surveys and is based on DSM-IV criteria. It includes 7 items, each beginning with: "Over the last 2 weeks, how often have you been bothered by the following problems?" Response categories are on a 4-point scale ranging from (0) "Not at all" to (3) "Nearly every day". The established cut-off score of 10 or greater was used to identify individuals with moderate to severe anxiety symptoms, which has previously been validated in adult populations (Spitzer et al., 2006).

### 2.3. Exposure measure

Loneliness was measured with a single item from the Center for Epidemiological Studies Depression (CES-D) scale (Radloff, 1977). The survey did not include the entire CES-D scale but did include the single item which has been used to measure loneliness in many epidemiological studies including in older adults (Shiovitz-Ezra and Ayalon, 2011). The item asked, "In the past 7 days, how often have you felt lonely?" The four categories were "Rarely or none of the time (Less than 1 day)," "Some or a little of the time (1–2 days)," "Occasionally or a moderate amount of the time (3–4 days)," and "Most or all of the time (5–7 days)."

### 2.4. Covariates

Covariates included age (18 to 29 years; 30 to 39 years; 40 to 49 years; 50 to 59 years; 60 to 69 years, 70+ years), gender (male, female, non-binary), educational attainment (high school or less, some post-secondary, college degree/diploma, university degree/diploma), household income in Canadian dollars (less than \$40,000; \$40,000-\$79,000; \$80,000-\$100,000; \$120,000+; prefer not to answer), marital status (married or living with partner, single/divorced/separated/widowed), living alone (yes or no), survey wave (1 to 7). Depression and hopefulness were also measured as single items from the CES-D scale (Radloff, 1977), which asked: "In the past 7 days, how often have you felt depressed?" and "In the past 7 days, how often have you felt hopeful about the future." The four categories were "Rarely or none of the time (Less than 1 day)," "Some or a little of the time (1–2 days)," "Occasionally or a moderate amount of the time (3–4 days)," and "Most or all of the time (5–7 days)." No other items from the CES-D were included in the survey.

### 2.5. Analysis

We assessed age and gender as effect modifiers for the association between loneliness and anxiety symptoms on the additive scale by directly estimating prevalence differences based on the modeling process outlined by Cheung (2007). Assessing effect modification on the additive scale is more consequential to public health as it allows for the identification of subpopulations that would benefit most from intervention (VanderWeele and Knol, 2014). We began the modeling process by identifying, from available options, models for a binary outcome and additive effects which would converge in order to assess the model for additive interactions (Cheung, 2007; Spiegelman and Hertzmark, 2005). A binomial identity model, and subsequently a modified Poisson model (Zou, 2004), both failed to converge. A model with the Normal distribution error term and identity link did converge. Linear regression with robust standard errors, also known as modified least-squares regression, has been shown to accurately estimate prevalence differences with binary outcome data (Cheung, 2007). This method corrects for the misspecified error term using the Huber-White sandwich estimator, which produces appropriate coverage of confidence intervals (Cheung, 2007; Zou, 2004). All initial models included identified covariates and all two- and the three-way interaction terms for loneliness, gender, and age. Higher order interaction terms that were not statistically significant

were removed. Models assessing gender as an effect modifier excluded the non-binary gender group due to small sample size ( $n = 55$ ), while all other regression analyses included the non-binary gender group as part of a main effect gender covariate. Participants with missing data were excluded from all regression analyses ( $n = 143$ ).

Graphs were used to aid in the interpretation of interaction terms and express the association between loneliness and anxiety symptoms conditional on levels of gender and age (demonstration of interaction as effect measure modification). We used multivariable logistic regression to estimate adjusted probabilities of anxiety symptoms for all levels of the interaction with covariates set to their reference levels (i.e., male gender, felt depressed rarely or none of the time in past 7 days (< 1 day), felt hopeful about the future most or all of the time in past 7 days (5–7 days), university degree, \$120k+ income, married/living with partner, living with other(s), and survey wave 1). Logistic regression was used to estimate adjusted probabilities in order to ensure that all values were

bounded between 0% and 100%; this property is not shared by linear models (Muller and MacLehose, 2014). Chi-square tests were also performed to assess for the independence of covariates, and loneliness frequencies were tabulated by gender and survey wave for descriptive purposes. All statistical analyses were conducted using SAS software, Version 9.4. (SAS Institute Inc., 2016).

### 3. Results

The characteristics of the pooled study sample stratified by anxiety symptoms are presented in Table 1. Approximately 21.7% of the sample scored 10 or higher on the GAD-7 indicating moderate to severe anxiety symptoms. Anxiety symptoms followed a slight U-shaped curve over the course of 2020 with the highest estimates in the earlier months of the pandemic (May 8–12: 25.5%; May 28 to June 1: 21.5%) and as the second wave of infection began in the fall (September 18–22: 21.1%;

**Table 1**  
Sample characteristics by anxiety symptoms among Canadian adults aged 18+ years during the COVID-19 pandemic.

Variables	Total sample $n = 7021$		Moderate to severe anxiety symptoms (GAD-7 10+) $n = 1525$		No to mild anxiety symptoms (GAD-7 <10) $n = 5496$		$X^2$ p-value
	n		n	(%)	n	(%)	
<b>Felt lonely in past 7 days</b>							<0.001
Most or all of the time (5–7 days)	597		428	(71.7%)	169	(28.3%)	
Occasionally or a moderate amount of the time (3–4 days)	964		445	(46.2%)	519	(53.8%)	
Some or a little of the time (1–2 days)	1845		401	(21.7%)	1444	(78.3%)	
Rarely or none of the time (< 1 day)	3615		251	(6.9%)	3364	(93.1%)	
<b>Age</b>							<0.001
18 to 29 years	858		287	(33.4%)	571	(66.6%)	
30 to 39 years	1879		500	(26.6%)	1379	(73.4%)	
40 to 49 years	1000		248	(24.8%)	752	(75.2%)	
50 to 59 years	1148		253	(22.0%)	895	(78.0%)	
60 to 69 years	1299		178	(13.7%)	1121	(86.3%)	
70+ years	837		59	(7.0%)	778	(93.0%)	
<b>Gender</b>							<0.001
Male	3484		666	(19.1%)	2818	(80.9%)	
Female	3482		840	(24.1%)	2642	(75.9%)	
Non-binary	55		19	(34.5%)	36	(65.5%)	
<b>Felt depressed in past 7 days</b>							<0.001
Most or all of the time (5–7 days)	478		391	(81.8%)	87	(18.2%)	
Occasionally or a moderate amount of the time (3–4 days)	944		572	(60.6%)	372	(39.4%)	
Some or a little of the time (1–2 days)	1868		412	(22.1%)	1456	(77.9%)	
Rarely or none of the time (< 1 day)	3731		150	(4.0%)	3581	(96.0%)	
<b>Felt hopeful about future in past 7 days</b>							<0.001
Most or all of the time (5–7 days)	1262		153	(12.1%)	1109	(87.9%)	
Occasionally or a moderate amount of the time (3–4 days)	2117		349	(16.5%)	1768	(83.5%)	
Some or a little of the time (1–2 days)	2154		620	(28.8%)	1534	(71.2%)	
Rarely or none of the time (< 1 day)	1488		403	(27.1%)	1085	(72.9%)	
<b>Marital status</b>							<0.001
Married/living with partner	4398		880	(20.0%)	3518	(80.0%)	
Single/divorced/separated/widowed	2528		630	(24.9%)	1898	(75.1%)	
<b>Live alone</b>							0.102
Yes	1450		292	(20.1%)	1158	(79.9%)	
No	5545		1227	(22.1%)	4318	(77.9%)	
<b>Educational attainment</b>							0.276
High school or less	814		163	(20.0%)	651	(80.0%)	
Some post-secondary	1069		253	(23.7%)	816	(76.3%)	
College degree/diploma	1398		310	(22.2%)	1088	(77.8%)	
University degree/diploma	3679		795	(21.6%)	2884	(78.4%)	
<b>Household income (CAD)</b>							<0.001
<\$40,000	853		251	(29.4%)	602	(70.6%)	
\$40,000–79,999	1714		408	(23.8%)	1306	(76.2%)	
\$80,000–119,999	1603		344	(21.5%)	1259	(78.5%)	
\$120,000+	1706		322	(18.9%)	1384	(81.1%)	
Prefer not to answer	1145		200	(17.5%)	945	(82.5%)	
<b>Survey wave</b>							0.003
1 (May 8 to 12, 2020)	1005		256	(25.5%)	749	(74.5%)	
2 (May 28 to June 1, 2020)	1002		215	(21.5%)	787	(78.5%)	
3 (June 19 to 23, 2020)	1005		196	(19.5%)	809	(80.5%)	
4 (July 10 to 14, 2020)	1003		193	(19.2%)	810	(80.8%)	
5 (September 18 to 22, 2020)	1003		212	(21.1%)	791	(78.9%)	
6 (November 27 to December 1, 2020)	1003		244	(24.3%)	759	(75.7%)	
7 (March 19 to 23, 2021)	1000		209	(20.9%)	791	(79.1%)	

Note: Totals do not match for all variables due to missing data.

November 27 to December 1: 24.3%), and the lowest estimates in the intervening spring and summer months (June 19–23: 19.5%; July 10–14 19.2%) when harsher restrictions were lifted and COVID-19 case counts were lower (Canadian Institute for Health Information, 2021). In March 2021 at the end of Canada’s second wave, anxiety symptoms were reduced (20.9%). We found that 22.2% of the overall sample reported feeling lonely at least occasionally (3+ days) in the past week. Chi-square tests showed that loneliness, age, gender, marital status, household income, and survey wave were significantly related to anxiety symptoms.

As shown in Table 2, the distribution of loneliness frequency was stable across the seven survey waves and chi-square tests suggested that the gender ratio did not differ significantly across the seven survey waves for any of the loneliness frequencies.

Based on modified least-squares regression modeling, the three-way interaction of loneliness\*age\*gender was not statistically significant ( $X^2(15) = 20.05; p = 0.170$ ). The loneliness by gender interaction was also not statistically significant when assessed on its own ( $X^2(3) = 4.40; p = 0.221$ ). As shown in Table 3, age was a significant effect modifier for the association between loneliness and anxiety symptoms ( $X^2(15) = 44.91; p < 0.001$ ). The logistic regression model used to estimate adjusted probabilities of anxiety symptoms for graphing purposes is also presented in Table 3; however, caution should be used in interpreting interaction coefficients and significance tests on the log odds (multiplicative) scale (VanderWeele and Knol, 2014).

As shown in Fig. 1, greater frequency of loneliness in the past 7 days was associated with greater probability of anxiety symptoms for all age groups. However, the association was not as strong among those aged 70 years and older compared to other age groups. No discernible pattern of differences was observed for age groups under 70 years of age.

4. Discussion

Age significantly moderated the association between loneliness and anxiety symptoms, such that the association was not as strong among those aged 70+ years compared to all other age groups. Research suggests that older adults generally place more value on having a few high-quality relationships whereas young adults typically derive satisfaction from building and maintaining a large social network with many contacts (Nicolaisen and Thorsen, 2017; Wickens et al., 2021). Pandemic restrictions have disrupted people’s ability to gather in large groups and made it difficult to maintain a large social network, which may be disproportionately affecting younger adults. Furthermore, previous research suggests that there are age differences in how people cope with stressful situations, with younger adults seeking interpersonal social support, while older adults use more intrapersonal emotion-focused

coping (Folkman et al., 1987). Older adults also have more effective emotion regulation (Losada-Baltar et al., 2021), and may therefore be more resilient to mental health problems associated with pandemic loneliness. Research also suggests that different factors contribute to loneliness severity for different age groups, especially at transitional life stages – including entering adulthood (e.g., starting employment, moving out, etc.) and reaching older age (e.g., retirement, losing a loved one, etc.; Lim et al., 2020) – which may contribute to age differences in the association between loneliness and anxiety.

This study has important mental health policy implications as it raises questions about which age group should be targeted with loneliness interventions. From the beginning of the pandemic there has been concern for the wellbeing of older adults because they are at highest risk of illness and death from COVID-19. Physical distancing has made it especially difficult for many older adults to access family, friends, and social services upon which they are often functionally dependent (Hwang et al., 2020). Older adults are also not as capable of using virtual technology to maintain social connections or access mental health services during the pandemic (Armitage and Nellums, 2020; Hwang et al., 2020). Understandably, the vast majority of research on loneliness interventions has focused on older adults (Kahlon et al., 2021; Poscia et al., 2018; Williams et al., 2021). However, our data suggest that younger adults are significantly more likely to suffer from loneliness and associated anxiety symptoms during the COVID-19 pandemic. Public health interventions that reduce loneliness among younger adults may therefore have the greatest impact on the COVID-19 mental health crisis. Young adults in particular should be prioritized because they are still in a vulnerable neurodevelopmental period when most anxiety disorders and other mental health problems first begin to arise (Lijster et al., 2017). Emerging evidence suggests that digital mental health interventions hold promise for improving the mental health of youth in the context of the pandemic, but more research is needed for interventions that address loneliness specifically (Rauschenberg et al., 2021a, 2021b).

This study should be interpreted in light of several limitations. As this study used cross-sectional data, the directionality of the relationship between loneliness and anxiety symptoms cannot be determined and causation cannot be inferred. Previous longitudinal research suggests that a bidirectional relationship exists between loneliness and anxiety, but with a stronger association with loneliness as the origin (Domènech-Abella et al., 2019; Santini et al., 2020). Thus, it is likely that many people are feeling lonely as a result of the pandemic, which may be contributing to increased anxiety; but at the same time, those with previous anxiety problems may be more likely to feel lonely. This study did not collect data before the pandemic, limiting our ability to attribute our findings to the pandemic; though we note that many other studies suggest that the pandemic has led to increased loneliness,

Table 2  
Loneliness frequency in past 7 days by gender and survey wave.

Felt lonely in past 7 days	Gender	Wave 1	Wave 2	Wave 3	Wave 4	Wave 5	Wave 6	Wave 7	X <sup>2</sup> p-value
Rarely or none of the time (less than 1 day)	Males	270 (55.2%)	269 (53.3%)	302 (55.3%)	289 (54.7%)	281 (53.9%)	282 (56.5%)	284 (56.1%)	0.951
	Females	219 (44.8%)	236 (46.7%)	244 (44.7%)	239 (45.3%)	240 (46.1%)	217 (43.5%)	222 (43.9%)	
Some or a little of the time (1–2 days)	Males	138 (49.1%)	120 (47.1%)	105 (43.0%)	104 (43.5%)	130 (47.8%)	110 (41.5%)	122 (44.4%)	0.532
	Females	143 (50.9%)	135 (52.9%)	139 (57.0%)	135 (56.5%)	142 (52.2%)	155 (58.5%)	153 (55.6%)	
Occasionally or a moderate amount of the time (3–4 days)	Males	69 (47.3%)	74 (51.0%)	60 (46.5%)	74 (50.0%)	47 (38.8%)	67 (47.5%)	57 (45.2%)	0.557
	Females	77 (52.7%)	71 (49.0%)	69 (53.5%)	74 (50.0%)	74 (61.2%)	74 (52.5%)	69 (54.8%)	
Most or all of the time (5–7 days)	Males	27 (31.4%)	29 (34.5%)	34 (42.0%)	34 (43.6%)	39 (48.1%)	33 (36.7%)	34 (40.0%)	0.336
	Females	59 (68.6%)	55 (65.5%)	47 (58.0%)	44 (56.4%)	42 (51.9%)	57 (63.3%)	51 (60.0%)	

Note: Survey waves occurred May 8 to May 12, 2020 (Wave 1), May 28 to June 1, 2020 (Wave 2), June 19 to 23, 2020 (Wave 3), July 10 to 14, 2020 (Wave 4), September 18 to 22, 2020 (Wave 5), November 27 to December 1, 2020 (Wave 6), and March 19 to 23, 2021 (Wave 7); non-binary gender suppressed due to small cell sizes. Chi-square tests assessed for independence between gender and survey wave for each level of loneliness.



**Table 3**  
Multivariable modified least-squares and logistic regression models for anxiety symptoms (GAD-7 10+) including interaction terms.

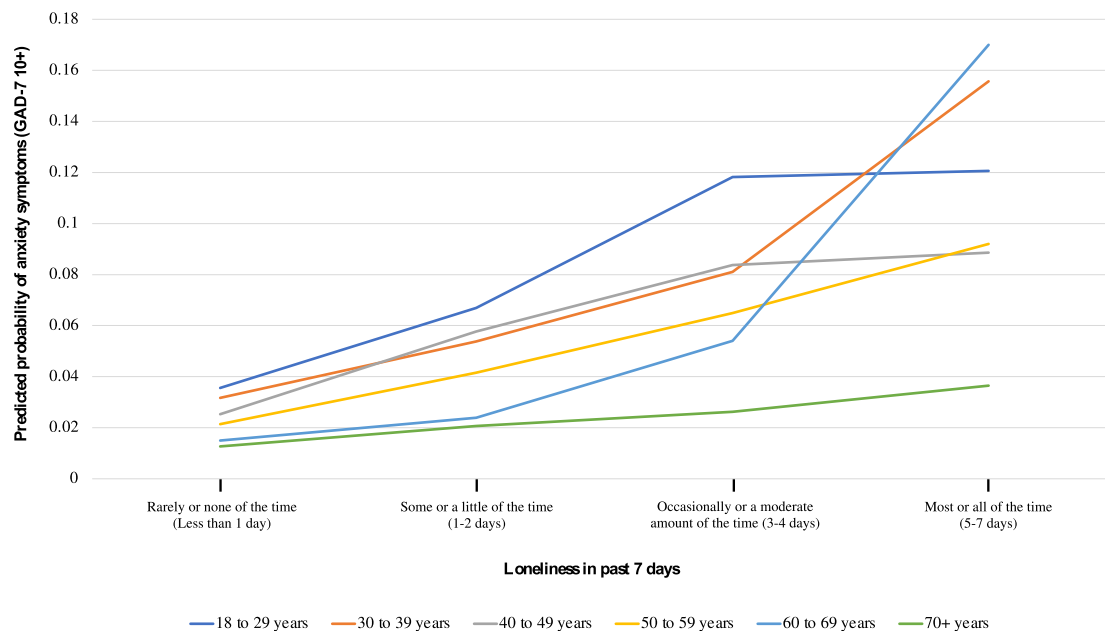
Variables	Modified least-squares model severe anxiety symptoms GAD-7 10+ (n = 6878)			Moderate to severe anxiety symptoms GAD-7 10+ (n = 6878)	Logistic model Moderate to severe anxiety symptoms GAD-7 10+ (n = 6878)		
	Coefficients (probability)	95%CI	Joint test p-value		Coefficients (log odds)	95%CI	Joint test p-value
<b>Intercept</b>	-0.003	-0.043 0.037	0.877		-4.350	-5.005 -3.695	<0.001
<b>Felt lonely in past 7 days</b> (Ref = Rarely or none of the time [ $< 1$ day])			<0.001				0.138
Most or all of the time (5-7 days)	0.024	-0.143 0.192			1.076	0.061 2.091	
Occasionally or a moderate amount of the time (3-4 days)	-0.003	-0.090 0.083			0.735	-0.080 1.549	
Some or a little of the time (1-2 days)	0.007	-0.033 0.047			0.491	-0.292 1.275	
<b>Age</b> (Ref = 70+ years)			<0.001				<0.001
18-29 years	0.046	0.010 0.082			1.052	0.354 1.749	
30-39 years	0.034	0.009 0.058			0.931	0.346 1.515	
40-49 years	0.016	-0.010 0.043			0.699	0.071 1.328	
50-59 years	0.009	-0.014 0.032			0.528	-0.096 1.152	
60-69 years	-0.002	-0.021 0.018			0.168	-0.472 0.808	
<b>Loneliness*age</b> (Ref= 70+ years and felt lonely rarely or none of the time ( $< 1$ day))			<0.001				0.246
18-29 years and felt lonely most or all of the time (5-7 days)	0.208	0.023 0.393			0.235	-0.956 1.426	
30-39 years and felt lonely most or all of the time (5-7 days)	0.260	0.084 0.435			0.653	-0.448 1.754	
40-49 years and felt lonely most or all of the time (5-7 days)	0.177	-0.016 0.370			0.244	-0.940 1.428	
50-59 years and felt lonely most or all of the time (5-7 days)	0.192	0.006 0.378			0.457	-0.694 1.608	
60-69 years and felt lonely most or all of the time (5-7 days)	0.309	0.119 0.498			1.520	0.290 2.750	
18-29 years and felt lonely occasionally or a moderate amount of the time (3-4 days)	0.000	0.000 0.000			0.554	-0.432 1.540	
30-39 years and felt lonely occasionally or a moderate amount of the time (3-4 days)	0.236	0.120 0.351			0.257	-0.627 1.142	
40-49 years and felt lonely occasionally or a moderate amount of the time (3-4 days)	0.171	0.067 0.276			0.523	-0.437 1.483	
50-59 years and felt lonely occasionally or a moderate amount of the time (3-4 days)	0.202	0.081 0.324			0.420	-0.521 1.360	
60-69 years and felt lonely occasionally or a moderate amount of the time (3-4 days)	0.156	0.044 0.269			0.585	-0.393 1.563	
18-29 years and felt lonely some or a little of the time (1-2 days)	0.118	0.005 0.231			0.172	-0.776 1.121	
30-39 years and felt lonely some or a little of the time (1-2 days)	0.000	0.000 0.000			0.061	-0.787 0.909	
40-49 years and felt lonely some or a little of the time (1-2 days)	0.088	0.019 0.158			0.366	-0.540 1.272	
50-59 years and felt lonely some or a little of the time (1-2 days)	0.067	0.013 0.122			0.193	-0.717 1.103	
60-69 years and felt lonely some or a little of the time (1-2 days)	0.094	0.029 0.159			-0.018	-0.953 0.918	
<b>Gender</b> (Ref = Male)			0.646				0.634
Female	0.007	-0.009 0.023			0.064	-0.089 0.218	
Non-binary	0.026	-0.085 0.137			0.236	-0.580 1.053	
<b>Felt depressed in past 7 days</b> (Ref = Rarely or none of the time [ $< 1$ day])			<0.001				<0.001
Most or all of the time (5-7 days)	0.596	0.546 0.645			3.651	3.318 3.985	
Occasionally or a moderate amount of the time (3-4 days)	0.445	0.408 0.483			2.853	2.616 3.090	
Some or a little of the time (1-2 days)	0.123	0.102 0.144			1.417	1.202 1.632	
<b>Felt hopeful about future in past 7 days</b> (Ref = Most or all of the time [5-7 days])			<0.001				<0.001
Rarely or none of the time ( $< 1$ day)	0.030	0.009 0.052			0.447	0.162 0.733	
Some or a little of the time (1-2 days)	0.040	0.020 0.061			0.535	0.266 0.803	
Occasionally or a moderate amount of the time (3-4 days)	-0.002	-0.021 0.016			0.158	-0.122 0.437	
<b>Education</b> (Ref = University degree / diploma)			0.415				0.351
High school or less	-0.015	-0.040 0.010			-0.145	-0.409 0.118	
Some post-secondary	0.009	-0.013 0.032			0.121	-0.099 0.341	
College degree / diploma	0.003	-0.018 0.023			0.051	-0.147 0.249	
<b>Household income</b> (Ref = \$120,000+)			0.535				0.488
<\$40,000	0.014	-0.017 0.045			0.137	-0.143 0.416	
\$40,000-\$79,000	0.001	-0.022 0.025			0.029	-0.195 0.252	
\$80,000-\$119,000	-0.008	-0.029 0.014			-0.067	-0.288 0.155	
Prefer not to answer	-0.011	-0.034 0.013			-0.109	-0.372 0.154	
<b>Marital status</b> (Ref = Married/living with partner)			0.008				0.005
Single/divorced/separated/widowed	-0.033	-0.056 -0.009			-0.292	-0.495 -0.089	
<b>Live alone</b> (Ref = No)			0.003				<0.001
Yes	0.041	0.014 0.068			0.444	0.205 0.683	
<b>Survey wave</b> (Ref = 1 [May 8 to 12, 2020])			0.040				0.052
2 (May 28 to June 1, 2020)	-0.041	-0.070 -0.012			-0.384	-0.658 -0.110	
3 (June 19 to 23, 2020)	-0.038	-0.067 -0.010			-0.354	-0.630 -0.078	
4 (July 10 to 14, 2020)	-0.040	-0.068 -0.013			-0.373	-0.652 -0.095	
5 (September 18 to 22, 2020)	-0.036	-0.064 -0.008			-0.332	-0.607 -0.057	
6 (November 27 to December 1, 2020)	-0.017	-0.047 0.012			-0.164	-0.431 0.103	
7 (March 19 to 23, 2021)	-0.034	-0.062 -0.006			-0.312	-0.587 -0.037	

Notes: Ref = reference category; 95% CI = 95% confidence interval.

\* Coefficients in logistic regression model not reported as prevalence odds ratio due to difficulty in interpretability of effects involved in interactions. Interaction by age is illustrated in Fig. 1.

anxiety, and other mental health problems at the population level (Bu et al., 2020; Czeisler et al., 2021; Li and Wang, 2020; McGinty et al., 2020; Pan et al., 2021; Pierce et al., 2020; Twenge and Joiner, 2020; Varga et al., 2021). Data were collected online and the response rate was modest, both of which may have introduced selection bias. However, it should be noted that roughly 94% of Canadians have access to the Internet overall (Statistics Canada, 2019). Quota-sampling was also used

to approximate the Canadian English-speaking population in terms of age, gender, and region. This allowed our study to achieve better representativeness compared to many other online studies regarding loneliness and mental health during the pandemic which oversampled females, likely owing to their use of snowball or convenience sampling (González-Sanguino et al., 2021; Horesh et al., 2020; Jia et al., 2020; Losada-Baltar et al., 2021; Palgi et al., 2020).



**Fig. 1.** Illustration of the relationship between loneliness and estimated adjusted probability of anxiety symptoms modified by age group.

Note: Adjusted probabilities of anxiety symptoms were estimated from the logistic regression model in Table 3, assuming all other covariates held at reference values (male gender, university degree, \$120k+ income, felt depressed rarely or none of the time in past 7 days (< 1 day), felt hopeful about future most or all of the time in past 7 days (5–7 days), married/living with partner, living with other(s), and survey wave 1).

We also used a single direct item to measure loneliness, which relies on participants' subjective understanding of loneliness. Other studies examining loneliness and mental health during the pandemic have predominantly used multidimensional indirect scales such as the UCLA Loneliness Scale (Russell et al., 2020), which capture different aspects of loneliness. Previous research suggests that the single direct item may have a different age distribution compared to multidimensional indirect measures (Nicolaisen and Thorsen, 2014), which could have contributed to the age difference we observed. The single direct item has also led to underreporting of loneliness among males due to stigma, especially when collected in person or over the phone (Nicolaisen and Thorsen, 2014; Shiovitz-Ezra and Ayalon, 2011). It is therefore possible that we captured more severe loneliness among men, which perhaps masked a gender difference in the association between loneliness and anxiety. However, we note that our data collection was conducted online and anonymously during a period of physical distancing and lockdowns, which may have reduced social desirability bias in relation to people's self-reports of loneliness.

Finally, it is important to distinguish the concepts of loneliness and social isolation to provide proper context for the age difference we observed. Loneliness is defined as a perceived discrepancy between actual and desired levels of social relationships while social isolation is an objective measure of the quantity of one's social contacts (Lim et al., 2020). Social isolation does not necessarily reflect a person's subjective desire and emotional need for social connection, as one can be socially satisfied with little social contact. Our study did not measure social isolation, but rather people's subjective feeling of loneliness, which could have a different meaning to different age groups (Nicolaisen and Thorsen, 2014), especially during the pandemic. It is possible that older adults are not experiencing mental health problems associated with loneliness as much as younger people because they do not desire as much social contact and therefore are better able to meet their social and emotional needs during the pandemic, despite objectively being more socially isolated.

To our knowledge, this study is the first to explore both age and gender differences in the association between loneliness and anxiety during the COVID-19 pandemic. We used a large national population-

based sample, with data collected in multiple waves over the first year of the pandemic. Given the challenges of collecting timely population-based mental health data during the pandemic, our study provides much-needed information that can help inform the COVID-19 mental health policy response and responses to future infectious disease events. Our findings further highlight the need for evidence-based interventions that address loneliness among younger adults in the context of physical distancing and lockdowns. Such interventions might be necessary to prevent downstream increases in chronic mental health problems at the population level.

#### CRediT authorship contribution statement

**André J. McDonald:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Christine M. Wickens:** Conceptualization, Project administration, Investigation, Writing – review & editing. **Susan J. Bondy:** Methodology, Writing – review & editing. **Tara Elton-Marshall:** Project administration, Investigation, Writing – review & editing. **Samantha Wells:** Project administration, Investigation, Methodology, Writing – review & editing. **Yeshambel T. Nigatu:** Project administration, Investigation, Methodology, Writing – review & editing. **Damian Jankowicz:** Project administration, Investigation, Writing – review & editing. **Hayley A. Hamilton:** Project administration, Investigation, Methodology, Writing – review & editing.

#### Declaration of Competing Interest

None.

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## Data access

Data is publicly available and can be accessed using the following link: <https://www.delvinia.com/camh-coronavirus-mental-health/>

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