

Are quantitative targets for social network size and interaction frequency appropriate for public health guidelines on social connection? Evidence from loneliness and related mental health outcomes

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ABSTRACT

Introduction: Public health guidelines for social connection seek to address loneliness and its health consequences at the population level. Although some approaches suggest specific numeric targets (e.g., frequency of social interaction), the empirical basis for these thresholds remains unclear. We aimed to identify such thresholds for loneliness and related mental health outcomes and test their stability across strata of mental health.

Methods: We analyzed repeated cross-sectional data from the Canadian Social Connection Survey collected between 2021 and 2024 ($n = 1,325$). Primary outcomes were emotional and social loneliness. Secondary outcomes were depressive symptoms, generalized anxiety symptoms, and self-esteem. The exposures were number of close friends and number of days in the past week spent with friends. Generalized additive models assessed non-linear associations, and segmented regression estimated approximate breakpoints if threshold emerged.

Results: Significant non-linear associations were found between number of close friends and both emotional and social loneliness. Approximate breakpoints at which larger improvements stopped differed by outcome: up to 3.5 close friends for emotional loneliness and 6.7 for social loneliness. Breakpoints for larger improvements of depressive symptoms, generalized anxiety, and self-esteem ranged from 3.0 to 3.7 close friends, aligning more closely with emotional loneliness. Threshold-like patterning for days spent with friends was apparent for some secondary outcomes, but not loneliness. Stratified analyses suggested more heterogeneous patterns among participants screening positive for depression and anxiety.

Conclusions: Outcome-specific breakpoints suggest potential thresholds for social connection, but variation across outcomes and population subgroups limits their interpretation as universal numeric targets or population-level guidelines.

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1. Introduction

Loneliness and social disconnection are major public health concerns, with a robust body of evidence demonstrating their adverse effects on mental and physical health, and premature mortality. Research consistently shows that both emotional and social loneliness are associated with elevated risk for depression, anxiety, cognitive decline, cardiovascular disease, and early death (Aartsen et al., 2024; Wang et al., 2023, p. 202). Emotional loneliness refers to the subjective experience of lacking a close emotional attachment whereas social loneliness refers to belonging to a broader social network.

These consequences are neither trivial nor isolated but reflect broader societal patterns in which declining social participation, and reduced community engagement—i.e., social loneliness—are creating environments where meaningful social ties are increasingly difficult to develop or maintain, resulting in emotional loneliness or the lack of close, intimate emotional attachment. As a result, loneliness has emerged both as an individual experience and population-level problem requiring coordinated public health action (Holt-Lunstad, 2017).

Public health guidelines have long been used as a mechanism for mobilizing “whole-of-government” responses to complex health issues (Freiler et al., 2013), including dietary and physical activity. Clear, population-level recommendations can shift social norms, guide practitioners, inform service design, and generate political will (Allen et al., 2018; Pollack Porter et al., 2018). Efforts to articulate national guidelines for social connection represent the first attempt to extend this model to the domain of relational health (Goldman et al., 2026). By establishing a shared understanding of the importance of social connection and by identifying concrete strategies for strengthening it, such guidelines have the potential to catalyze coordinated action across health systems, workplaces, schools, municipalities, and community organizations (Freiler et al., 2013; Ortenzi et al., 2022).

Two major initiatives have shaped the emerging landscape of social connection guidelines. The first was led by Julianne Holt-Lunstad and colleagues, who proposed a set of candidate quantitative targets based on available research (Holt-Lunstad, 2023). These targets included specific thresholds for network size, social interaction frequency, and diversity of relational sources. This work was an important first step in articulating measurable markers of social health. However, there are inherent limitations to relying on universal numeric cutoffs, particularly given substantial variability in individual needs and nuanced contextual factors as they relate to loneliness (Badman et al., 2022; Yust et al., 2023). The second initiative was the Canadian National Recommended Public Health Guidelines for Social Connection, developed by Card and colleagues (Card et al., 2025; Refol et al., 2025). In contrast to the Holt-Lunstad proposal, the Canadian guidelines intentionally avoid quantitative thresholds. Instead, they emphasized universal design principles focused on accessibility, inclusion, and environmental conditions that enable connection for all people, regardless of personal circumstances (e.g., “Make social connection a priority throughout your life”). This shift reflects a broader trend in public health guidance, where many contemporary guidelines are moving away from absolute quantitative prescriptions in recognition of the complexity and heterogeneity of population needs (Chaput, 2025; Tinetti et al., 2024).

Notwithstanding, questions remain as to whether quantitative criteria can meaningfully complement or strengthen universal design-style guidelines. Advocates of numeric thresholds argue that clear metrics can help with screening, surveillance, and evaluation. Others caution that the evidence base does not support universal cutoffs, and that applying numeric targets may produce misleading or inequitable conclusions (Tinetti et al., 2024). One of the main arguments against numerical cutoffs for social network size or interaction frequency is the influence of social norms and individual expectations on the experience of loneliness (Heu, 2025). A recent analysis of loneliness data across all 27 European Union member states, for example, suggests that comparable amounts of social interaction lead to varying feelings of loneliness

because people have diverse social preferences (Mauri, 2026), which become more relevant across different lifespan stages (Danvers et al., 2023; Pardede & Kovač, 2023).

To date, few studies have empirically examined the stability, variability, or population-level reliability of such quantitative thresholds for social connection (Holt-Lunstad, 2023). In the current study, we evaluated whether candidate numeric thresholds for social connection were consistent across outcomes and population subgroups. First, we examined whether threshold-like patterns in the number of close friends and days spent socializing with friends were observed for emotional and social loneliness. Second, we assessed whether the location of any apparent breakpoints varied when these same indicators were evaluated against related mental health outcomes, including depressive symptoms, generalized anxiety symptoms, and self-esteem. Third, we examined whether these exposure-outcome patterns differed across strata defined by depression and anxiety screening status. Taken together, these analyses were intended to assess whether universal quantitative cutoffs are empirically stable enough to serve as a basis for population-level social connection guidelines.

2. Methods

Our study used repeated cross-sectional data from the Canadian Social Connection Survey (Card et al., 2025; Refol et al., 2025), an online survey of Canadians aged 16 years and older, collected yearly between 2021 and 2024. Respondents were recruited through English and French advertisements placed on Facebook, Twitter, Instagram, and Google, and data were collected using Qualtrics. Targeted recruitment procedures were used to reduce demographic imbalances across age, gender, and geography. Participants who completed the survey were eligible to enter a prize draw for a CAD \$200 cash prize. All respondents provided informed consent, and the study received ethics approval from the Research Ethics Boards of Simon Fraser University (Approval No. 30000986) and the University of Victoria (Approval No. 21-0115). We excluded baseline data from 2021 due to evidence of factor instability (tested through multi-group CFA) in our measure of social and emotional loneliness—i.e., the 6-item De Jong Gierveld Loneliness Scale (DJGLS-6)—during that period compared to all other years (probably due to COVID), as well as differences in the response format for our exposure measures at baseline, which used grouped rather than detailed categories.

2.1. Variables

2.1.1. Primary outcomes

Our primary outcomes were *emotional loneliness* and *social loneliness* (). Both constructs were operationalized through the DJGLS-6, which has been thoroughly validated and used in multiple countries (De Jong Gierveld & Van Tilburg, 2006; Surkalim et al., 2022), which asks respondents to report agreement with six statements reflecting the presence or absence of emotional and social loneliness, including experiences of emptiness, missing close relationships, and having a sufficient or reliable social network, using a three-category response format (yes, more or less, no). Distinguishing emotional from social loneliness was important for this study because these dimensions reflect conceptually different aspects of disconnectedness and may not be similarly associated with quantitative indicators of social connection. Emotional loneliness captures the perceived absence of close, intimate, or attachment-based ties, whereas social loneliness reflects deficits in broader social integration or network belonging.

Because our objective was to test whether universal numeric thresholds for social connection were stable across outcomes, separating these subscales allowed us to assess whether the same number of friends or days spent socializing were similarly associated with both relational domains, rather than assuming loneliness is a unitary construct. Factor scores for each construct were estimated by first fitting a confirmatory

factor analysis (CFA) and then deriving scores using the CFA model-implied loadings with weighted least squares means and variance-adjusted estimation. This method was chosen due to uneven loadings for one of the items.

2.1.2. Secondary outcomes

Our *secondary outcomes* were (1) depressive symptoms in the past two weeks, (2) generalized anxiety symptoms in the past two weeks, operationalized through the PHQ-2 and the GAD-2 scales (range for both scales: 0 to 6), respectively (Kroenke et al., 2003, 2007), and (3) self-esteem, evaluated through the Rosenberg's Self-Esteem Scale (range: 10 to 40) (Rosenberg, 1979). These secondary outcomes were based on data availability, clinical relevance, and convergent validity.

2.1.3. Coexposures

The main co-exposures for which we searched for thresholds were (1) the number of “close friends you have” and (2) the number of days in which the participant spent “at least 5 min socializing with ... friends” during the preceding week. The number of close friends was capped at 11 to limit the influence of extreme values and to avoid low-cell ($n < 5$) counts. Whereas other indicators were available through CSCS, these two are closely aligned with the indicators proposed by Holt-Lunstad (2023) and were significantly associated with overall loneliness in a preliminary analysis (see Supplementary Fig. S1).

2.1.4. Covariates

Other covariates included categorical variables for gender (Man, Woman, Nonbinary), age (categorized into 10-year intervals beginning at age 16-24 through 65-74, with an open-ended category for individuals aged ≥ 75 years), household income (Less than \$15,000, \$15,000 to \$29,999, \$30,000 to \$59,999, \$60,000 to \$99,999, \$100,000 or higher), ethnicity (White, Indigenous, Other), and retirement status (Retired, Not Retired). Covariate data was collected at baseline (2021).

2.2. Statistical analyses

2.2.1. Main analysis

Given that this study explores potential threshold effects across multiple outcomes, a complete case analysis was employed to ensure consistent comparability of observations across models and to avoid introducing differential sample composition arising from outcome-specific missingness. For similar reasons, the self-esteem scale was transformed to “poor self-esteem” by using the inverted values of the original scale. A general additive model (GAM) with tensor smooth was used to visualize the joint non-linear effects of both main exposures on social and emotional loneliness. Because the tensor product smooth was used primarily to characterize the joint exposure surface, we fit a second GAM with additive smooth terms to examine the marginal non-linear association of each social connection indicator with the outcome more directly, using cubic regression splines. Time spent with friends was restricted to five basis functions to account for the limited range of weekdays. A final GAM model adjusted for age group, household income, retirement status, and ethnicity. All models were fit assuming a Gaussian error distribution with an identity link, consistent with standard linear regression assumptions. Evidence of non-linearity was assessed using the effective degrees of freedom (EDF) of the smooth terms, where an $EDF \approx 1$ indicates an approximately linear relationship and EDF closer to 2 or above indicates increasing departures from linearity (e.g., potential threshold or nonlinear effects) (Wood et al., 2016). When the GAMs suggested threshold-like or diminishing-returns patterns, we fit segmented regression models (Fasola et al., 2018) to estimate approximate breakpoints at which the slope of the association changed. Slopes for each segment before and after the estimated breakpoint are reported.

2.2.2. Stratified analyses

We subset the data into four mutually exclusive groups based on screening positive or negative for (1) depression ($PHQ-2 \geq 3$) and (2) generalized anxiety ($GAD-2 \geq 3$) (Kroenke et al., 2003, 2007). The main analyses were repeated in each of these groups because past research suggested generalized anxiety played a moderating role in the loneliness-depression association (Wolters et al., 2023).

3. Results

3.1. Descriptive results

The final analytic sample included 1,325 participants with a median age of 62 years. Given the age distribution skewed towards older adults, roughly half of the participants were retired at the time of the survey. Most participants identified as White (86.7%), with 9.3% identifying as another ethnic group and 4.0% identifying as Indigenous. Three fourths of the sample identified as women. Most participants reported a household income below the national median (\$84,000 in 2021), but there was adequate representation from higher income groups (see Table 1). The median number of close friends was 3 (skew = 1.01, kurtosis = 0.52) and the median number days per week spent with

Table 1

Descriptive statistics of the analytic sample ($n = 1,325$).

Variable	Overall
	Mean (SD) n (%)
Emotional loneliness raw score	1.71 (1.17)
Social loneliness raw score	2.10 (1.14)
Emotional loneliness CFA score	-0.04 (0.60)
Social loneliness CFA score	-0.09 (0.61)
PHQ score	1.98 (1.89)
GAD score	2.04 (1.83)
Self-esteem	28.50 (6.70)
Number of close friends	3.55 (2.85)
Weekly days spent with friends	2.70 (2.19)
Gender (%)	
Woman	1,003 (75.7)
Man	264 (19.9)
Nonbinary	58 (4.4)
Age group (%)	
16-24	36 (2.7)
25-34	185 (14.0)
35-44	127 (9.6)
45-54	134 (10.1)
55-64	287 (21.7)
65-74	383 (28.9)
75+	173 (13.1)
Household income (%)	
High	242 (18.3)
Low	98 (7.4)
Lower-Middle	268 (20.2)
Middle	420 (31.7)
Upper-Middle	297 (22.4)
Retired = Yes (%)	687 (51.8)
Ethnic group (%)	
Indigenous	53 (4.0)
Other	123 (9.3)
White	1149 (86.7)

Note: Continuous variables are presented as mean (standard deviation), and categorical variables are presented as n (%). PHQ and GAD scores refer to PHQ-2 and GAD-2 symptom totals, respectively, with higher values indicating greater symptom burden. Self-esteem scores are based on the Rosenberg Self-Esteem Scale, with higher scores indicating higher self-esteem. Number of close friends refers to the self-reported count of close friends, capped at 11 to reduce the influence of extreme values. Weekly days spent with friends refers to the number of days in the past week on which respondents spent at least 5 min socializing with friends. This table is intended to describe the overall sample composition and the central tendency and variability of the key outcomes and exposure variables used in subsequent analyses.

friends was 2 (skew = 0.63, kurtosis = -0.64).

Overall, the CFA-derived loneliness scores demonstrated relatively symmetric distributions with low kurtosis (below -1.4 for both) and slight negative skew (emotional loneliness = -0.21; social loneliness = -0.55), suggesting that extreme loneliness scores were uncommon in the sample. PHQ and GAD scores, in contrast, presented slight positive skew (0.73 and 0.61, respectively), but the median for both metrics (2) was below the screening threshold. Self-esteem was roughly normally distributed. Overall, 730 participants (55.1%) screened negative for both depression and generalized anxiety, 184 (13.9%) screened positive for generalized anxiety only, 120 (9.1%) screened positive for depression only, and 291 (22.0%) screened positive for both depression and generalized anxiety.

3.2. Statistical analyses

The results are organized by outcomes and presented through tables and figures. Each table shows two results: the EDF derived from generalized additive models and its p-value. EDF values indicate the degree of non-linearity in the corresponding GAM smooth term, where values near 1 suggest an approximately linear association and larger values indicate increasing curvature or threshold-like patterning. For linear models, the slope and corresponding 95% confidence intervals are derived from the GAM. For non-linear patterns, the tables report the results of the corresponding segmented regression. In these models, “break” refers to the point at which the slope of the association changes. Models with a break have one slope before the break (Slope 1) and one after the break (Slope 2), each indicating the change in outcome associated with a one-unit increase in the exposure. Negative slopes indicate a desired effect (lower loneliness, fewer depressive or anxiety symptoms, and better self-esteem). Other coefficients are available as supplementary material.

3.2.1. Social loneliness

The tensor effect model indicated a significant non-linear interaction for social loneliness (EDF = 7.40; adjusted R^2 = 0.209; p < 0.001). Larger reductions in social loneliness were apparent as the reported number of friends was smaller (Fig. 1). This effect was also found in additive models (EDF = 2.8; p < 0.01) in both unadjusted and adjusted models (Supplementary Table S1). The segmented regression revealed the association was steeper up to an estimated breakpoint of 6.7 friends (SE = 0.7), with each additional close friend associated with a -0.108 difference in score (95% CI = -0.127 to -0.089; d = 0.18 per friend). Beyond this estimated breakpoint, the association was near null (β = 0.010, 95% CI = -0.040 to 0.060). The negative association between days spent with friends and social loneliness was mostly linear (β = -0.035, 95% CI = -0.050 to -0.021; d = 0.05 per day).

The inspection of subgroup surfaces showed that most of them contained enough variability across both exposures, with the exception of people who only screened positive for depression (no participant in this subgroup reported the highest levels of both co-exposures). Yet, data sparsity was evident at specific cross-sections of both exposures (Figs. 1 and 2). All things considered, the stratified analysis produced similar patterns to those of the main analysis for close number of friends, with different thresholds for people without any mental health condition (2.5 friends) and those who screened positive for depression (4.0 friends) compared to people who screened positive for anxiety only (8.0 friends) or for both conditions (7.0 friends). However, there was a slight upward trend on social loneliness for those who screened positive for anxiety (with or without depression) after the threshold, neither of which was statistically significant (Table 2).

Whereas the pattern was mostly consistent for the number of close friends, the effect of days spent with friends changed significantly depending on the mental health group. The association between time socializing and social loneliness among people without any condition mirrored that of the whole sample. However, there were non-linear

associations in all other groups. For people who screened positive for depression, social loneliness significantly increased up to 3.6 days and significantly decreased from that point onwards, whereas for people who screened positive for anxiety (with and without depression) there were significant reductions in social loneliness up to 4.0 days and non-significant increases in loneliness afterwards (Table 2 and Supplementary Table S2). The GAM surfaces suggested that, for people with anxiety, higher social loneliness was present when little time was spent with friends and people reported a high number of close friends. Whereas for people who screened positive for both conditions, higher loneliness was present with high levels of both co-exposures (Fig. 1).

3.2.2. Emotional loneliness

The tensor model for emotional loneliness also suggested non-linear interactions (EDF = 9.4; adjusted R^2 = 0.089; p < 0.001). The tensor plots suggested threshold effects (i.e., asymptotic declines) for certain subgroups only (see Fig. 2). In the additive models, the number of close friends showed significant non-linear effects in relation to emotional loneliness (EDF = 3.08; p < 0.01), indicating that increases in the number of close friends were associated with larger reductions in social and emotional loneliness at lower levels of friendship, with diminishing returns as the number of friends increased.

The days spent with friends also had a significant relationship with emotional loneliness, although it was mostly linear (EDF = 1.0; p < 0.01). In the fully adjusted models (see Supplementary Table S3), these effects remained virtually unchanged. However, the model fit improved significantly compared to the unadjusted estimates (adjusted R^2 = 0.193). According to the segmented regression results (see Table 3 and Supplementary Table S4), the association between number of close friends and emotional loneliness was steeper up to an estimated breakpoint of 3.5 friends (SE = 0.6), with each additional close friend associated with a -0.097 difference in emotional loneliness score (95% CI = -0.132 to -0.062; d = 0.16). Beyond this estimated breakpoint, the association was substantially attenuated (β = -0.014, 95% CI = -0.034 to 0.005). The estimated breakpoints from the unadjusted model (3.6) and the corresponding slope were similar to those observed in the main analysis (Supplementary Table S4).

Whereas the average breakpoint was 3.5 friends in the whole sample, those who screened negative for the measured mental health conditions had a lower threshold (2.6). However, the wide standard errors suggest this is not a statistically significant difference. The groups who screened positive for mental health conditions did not exhibit significant breakpoints. Most associations appear to be linear for both exposures (Table 3) and the effect direction could not be definitely established. Inspecting the GAM surfaces for emotional loneliness (Fig. 2) revealed an overall higher level of emotional loneliness among people who screened positive for both conditions compared to other groups. They also lacked linear patterns across different axis. Finally, this group also presents extreme social loneliness when the levels both co-exposures are at its highest.

3.2.3. Secondary outcomes

The thresholds for number of close friends on the secondary outcomes aligned more closely with those of emotional loneliness, with thresholds of 3.0 friends for depression (d = 0.17), 3.7 friends for generalized anxiety (d = 0.09) and 3.2 friends for poor self-esteem (d = 0.15). In contrast, the number of days had a breakpoint for depressive symptoms (1.6 days; d = 0.21) and poor self-esteem (1.5 days; d = 0.18), but not for generalized anxiety, which showed small but cumulative improvements for each additional day spent with friends (Table 4). For generalized anxiety, the GAM surface plot (Fig. 3) also suggested threshold effects, with distinct breakpoints at the lower and higher ends of the number of close friends axis. These multiple breakpoints may have averaged out in the segmented regression analysis, resulting in no detectable single threshold.

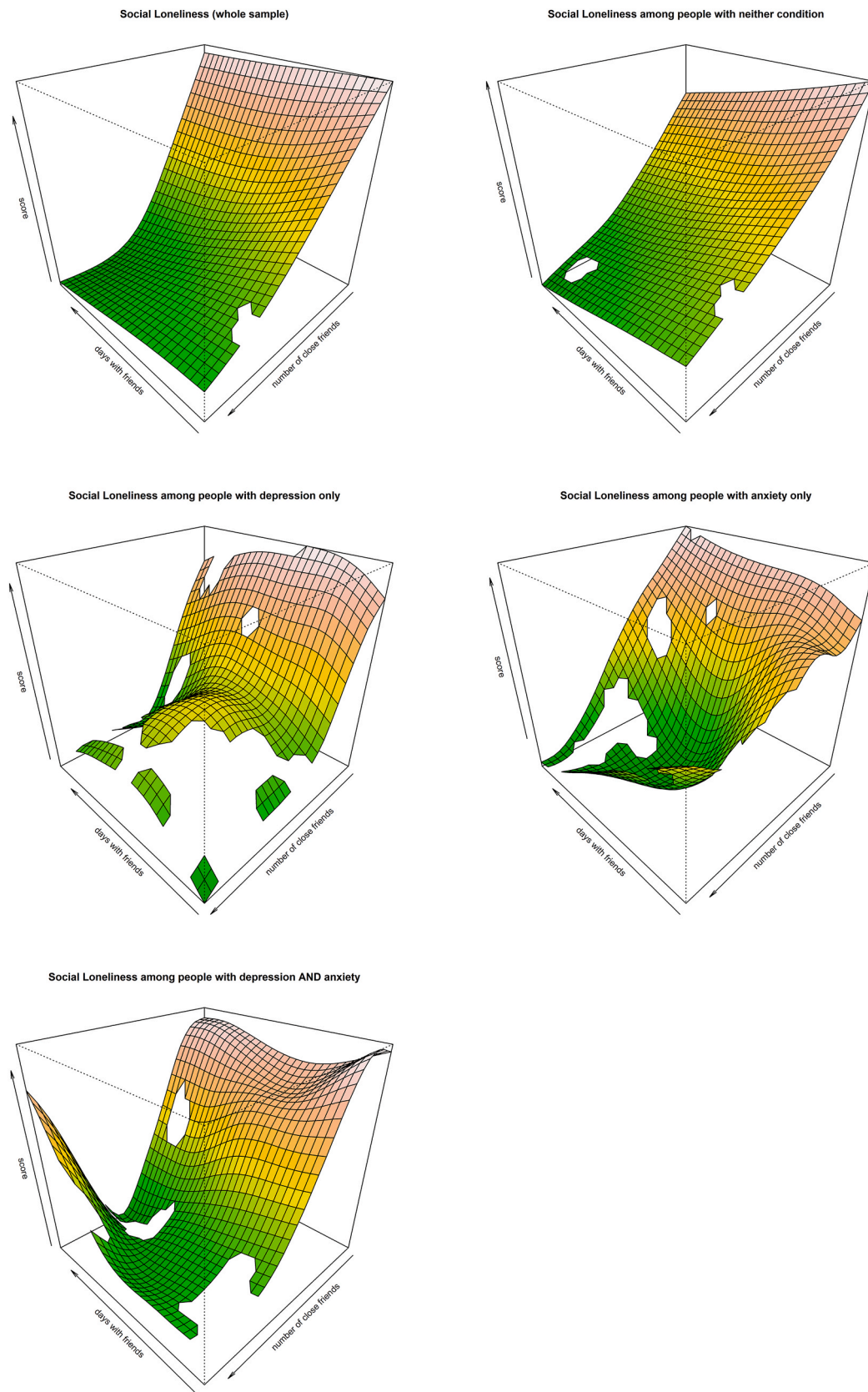


Fig. 1. 3D GAM response surfaces for social loneliness as a function of number of close friends and the number of days spent socializing with friends during the preceding week. Whole sample and stratified analysis are presented. Surfaces exclude regions with insufficient data support.

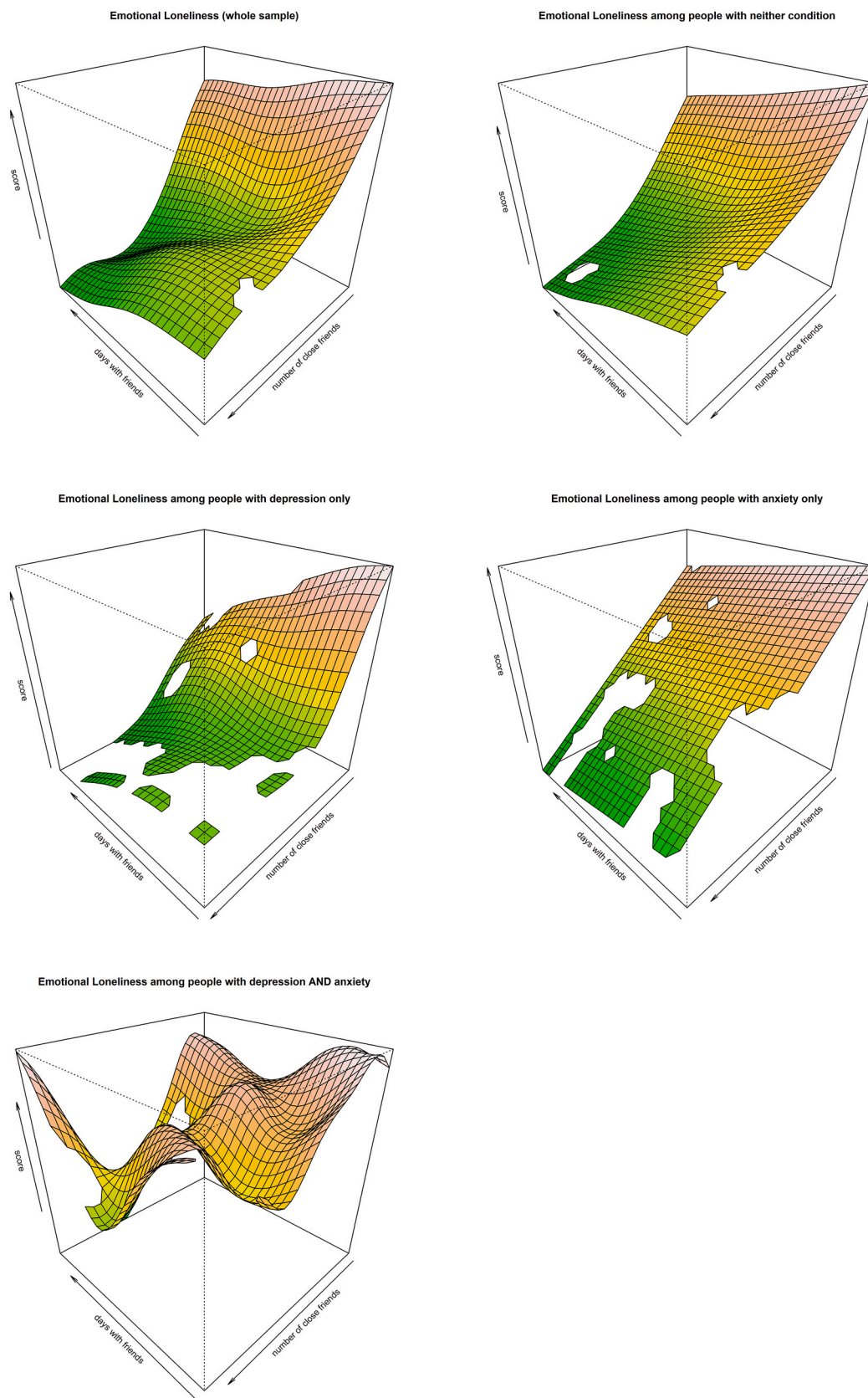


Fig. 2. 3D GAM response surfaces for emotional loneliness as a function of number of close friends and the number of days spent socializing with friends during the preceding week. Whole sample and stratified analysis are presented. Surfaces exclude regions with insufficient data support.

Table 2

Estimated degrees of freedom, breaks, and slopes for the effect of number of close friends and days spent with them on social loneliness. Whole-sample and stratified estimates are included.

Exposure	Group	EDF	Break (SE)	Slope 1 (95% CI)	Slope 2 (95% CI)
Number of close friends	Overall	2.86*	6.725 (0.719)	−0.108 (−0.127; −0.089)	0.010 (−0.040; 0.060)
	No condition	2.23*	2.544 (0.744)	−0.154 (−0.239; −0.068)	−0.049 (−0.070; −0.029)
	Depression	1.7*	4.0 (1.695)	−0.109 (−0.198; −0.020)	−0.024 (−0.101; 0.053)
	Anxiety	2.45*	8.0 (1.115)	−0.110 (−0.166; −0.054)	0.096 (−0.073; 0.265)
	Both disorders	3.61*	7.0 (1.205)	−0.098 (−0.126; −0.070)	0.079 (−0.069; 0.228)
Days spent with friends	Overall	1.0*	NA	−0.035 (−0.050; −0.021)	NA
	No condition	1.0*	NA	−0.036 (−0.056; −0.016)	NA
	Depression	2.17	3.609 (0.724)	0.112 (0.007; 0.216)	−0.138 (−0.262; −0.014)
	Anxiety	3.44	4.0 (0.949)	−0.077 (−0.178; 0.024)	0.099 (−0.023; 0.222)
	Both disorders	1.63	4.0 (1.735)	−0.058 (−0.102; −0.013)	0.057 (−0.093; 0.207)

Note: *p < 0.05. EDF = effective degrees of freedom; SE = standard error; CI = confidence interval; NA = not applicable.

4. Discussion

In this analysis, we examined a Canadian online sample to test whether the association between two exposures—the number of close friends and time spent with them—and loneliness exhibited threshold like effects. Besides social and emotional loneliness, we also explored these dynamics for anxiety, depression, and self-esteem. Finally, we explored differential effects by mental health status.

Emotional loneliness arises from the absence or perceived inadequacy of close, attachment-based ties and tends to be relieved by a small number of confiding relationships (Weiss, 1973). Social loneliness arises from limited integration in a wider network and is more sensitive to the breadth of one's social ties and the frequency of contact within them (Weiss, 1973). Because the two forms draw on different relational provisions, the same number of friends or amount of social contact may relate to each differently, and the strength and shape of these associations may shift among people with depression or anxiety, for whom the link between objective social contact and felt loneliness can weaken or even reverse (Wolters et al., 2023).

We found that average effects suggest the existence of thresholds in the negative association between our co-exposures and loneliness. These findings are consistent with the existing literature pertaining to the effect of the number of connections on both social and emotional loneliness (Lampraki et al., 2022). Threshold effects of social interaction were previously reported as “diminishing returns” in other outcomes, including well-being (Luo et al., 2022; Thompson et al., 2024).

Table 3

Estimated degrees of freedom, breaks, and slopes for the effect of number of close friends and days spent with them on emotional loneliness. Whole-sample and stratified estimates are included.

Exposure	Group	EDF	Break (SE)	Slope 1 (95% CI)	Slope 2 (95% CI)
Number of close friends	Overall sample	2.71*	3.487 (0.625)	−0.097 (−0.132; −0.062)	−0.014 (−0.034; 0.005)
	No condition	2.26*	2.654 (0.810)	−0.112 (−0.194; −0.029)	−0.016 (−0.035; 0.003)
	Depression	1.0	NA	−0.037 (−0.078; 0.004)	NA
	Anxiety	1.0*	NA	−0.112 (−0.194; −0.029)	NA
	Both disorders	1.48	7.0 (1.663)	−0.038 (−0.068; −0.007)	0.044 (−0.053; 0.141)
Days spent with friends	Overall sample	1.0	NA	−0.040 (−0.052; −0.029)	NA
	No condition	1.0*	NA	−0.029 (−0.048; −0.009)	NA
	Depression	1.0	NA	−0.005 (−0.054; 0.044)	NA
	Anxiety	1.0	NA	−0.021 (−0.063; 0.021)	NA
	Both disorders	1.0	NA	−0.023 (−0.048; 0.002)	NA

Note: *p < 0.05. EDF = effective degrees of freedom; SE = standard error; CI = confidence interval; NA = not applicable.

Table 4

Estimated degrees of freedom, breaks, and slopes for the association between number of close friends and days spent with friends and the secondary outcomes.

Exposure	Outcome	EDF	Break (SE)	Slope 1 (95% CI)	Slope 2 (95% CI)
Number of close friends	PHQ-2 score	4.543*	3.0 (0.516)	−0.322 (−0.433; −0.21)	−0.013 (−0.076; 0.050)
	GAD-2 score	2.196*	3.676 (0.998)	−0.157 (−0.267; −0.046)	0.009 (−0.053; 0.072)
	Poor self-esteem	2.252*	3.236 (0.675)	−0.980 (−1.353; −0.606)	−0.182 (−0.393; 0.028)
Days spent with friends	PHQ-2 score	2.351*	1.630 (0.601)	−0.411 (−0.727; −0.095)	0.049 (−0.115; 0.017)
	GAD-2 score	1.0*	NA	−0.071 (−0.118; −0.024)	NA
	Poor self-esteem	1.717*	1.484 (0.603)	−1.233 (−2.287; −0.179)	−0.120 (−0.340; 0.101)

Note: *p < 0.05. EDF = effective degrees of freedom; SE = standard error; CI = confidence interval; NA = not applicable; PHQ = Patient Health Questionnaire; GAD = Generalized Anxiety Disorder. .

4.1. Ideal thresholds

For social loneliness, a stronger association was found up to ~6.7 friends whereas for emotional loneliness, the association was stronger up to ~3.5 friends. The visual inspection of plots suggests the lower

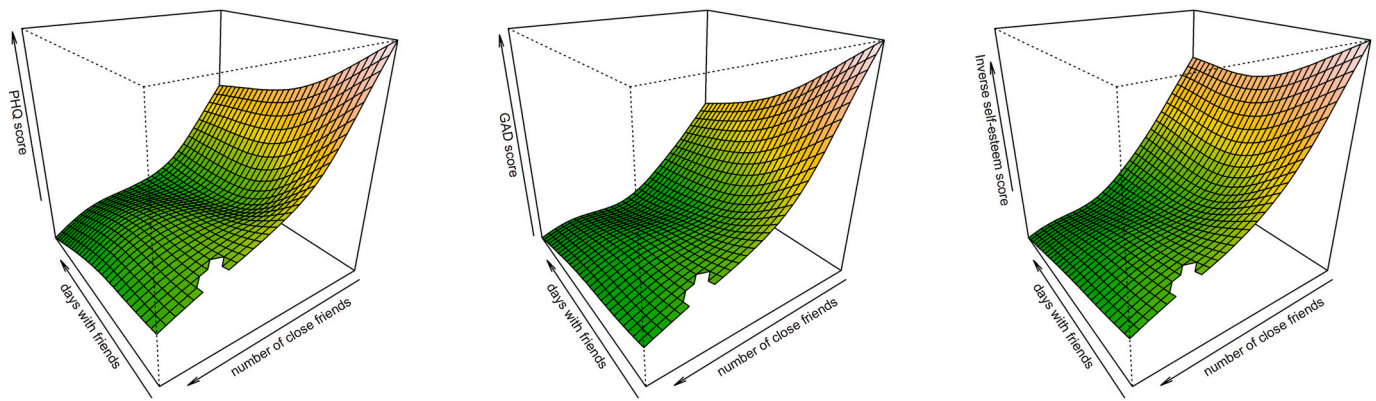


Fig. 3. 3D GAM response surfaces for our secondary outcomes as a function of number of close friends and the number of days spent socializing with friends during the preceding week. Surfaces exclude regions with insufficient data support.

threshold for emotional loneliness is partially attributable to participants spending less time socializing because as one approximates the lower values for this axis, the effect of having more close friends on emotional loneliness is weaker and tends to plateau. The thresholds for our secondary outcomes (range: 3.0 to 3.7 friends) aligned with the breakpoint found for emotional loneliness, consistent with previous studies (Gan et al., 2025; Wolters et al., 2023). Taken together, our findings suggest that bigger improvements across most outcomes occur when the number of friends change from 0 to ~4 friends, with the exception of social loneliness (where larger gains are found up to ~7 friends).

The negative association between time spent with friends was mostly linear for both social and emotional loneliness. However, the negative association between time with friends and depression and poor self-esteem was stronger up to 1.6 and 1.5 days per week, respectively. For anxiety, the average effect was linear, but the surface plot also suggested threshold effects with different pointbreaks at the higher and lower ends of the close number of friends axis. A post-hoc test that used the same methods we reported, but assumed non-linearity, estimated such a breakpoint at 1.7 days.

Whereas previous studies focused on health risks arising from obesity, hypertension, and metabolic dysregulation found that having more than 6 or 7 friends was associated with better health outcomes (Yang et al., 2013, 2016), our results show that formal testing of breakpoints is feasible and future research should establish whether the association between the size of the social network and other health outcomes converge at similar breakpoints. Such research has the potential to inform existing discussions about the role of social connection as a determinant of health (Anderson & Fowers, 2020; McMahon et al., 2024; Tinaikar & Schrauben, 2024).

Time socializing generated substantially more improvements from 0 to ~2 days for depression and self-esteem (there were also benefits for anxiety but not particularly on this period). As with our previous exposure, past research has also found that spending at least one day per week socializing is beneficial, but without testing for optimal breakpoints (Yang et al., 2013, 2016). Based on these findings, it seems reasonable to suggest spending at least 2 days per week socializing with friends. However, additional benefits to counter social and emotional loneliness are more likely if people are willing and able to spend socializing as much time as possible.

4.2. Patterns associated with mental health challenges

We also explored the complex association between our co-exposures and loneliness among people who screened positive for anxiety, depression, or both conditions. These models were limited by having fewer participants with a high number of close friends (particularly for those who screened positive for depression) and simultaneously

spending most days of the week socializing (across all groups who screened positive for either condition). For social loneliness, the bigger gains stopped sooner for participants who screened negative for both conditions (up to ~2 friends) and those who screened positive for depression (up to ~4 friends) compared to screening positive for anxiety (~8 friends) or both conditions (~7 friends), which were more inline with the whole-sample breakpoint.

The 3D surfaces suggested that having many close friends but spending little to no time with them was associated with high levels of social loneliness among people who screened positive for anxiety. In contrast, high levels of both co-exposures associated with increased social loneliness among people who screened positive for both conditions. Given reporting high values across a survey is suggestive of mischievous responses (Delgado-Ron et al., 2024), we inspected the data to find other patterns suggestive of this behaviour based on the existing literature (e.g., male gender, young age, higher values for measures that are negatively correlated with the outcomes) (Delgado-Ron et al., 2024). We did not find a consistent pattern of mischievous responses; however, the small number of participants was insufficient for formal testing.

Previous studies have found complex patterns among people with depression, including an inverted U-shaped association between number of friends and loneliness among a sample of high school students in the United States (Falci & McNeely, 2009). Therefore, we cannot rule out the possibility that the association observed in our study represents a true effect. Paradoxical effects on the association between social connection and loneliness were also reported by Wolters and colleagues (2023).

The stratified analyses for emotional loneliness revealed that most subgroups shared similar patterns with the exception of people who screened positive for both conditions. This group presented an overall increased level of emotional loneliness that likely influenced the plateau described in the whole-sample analysis. As with social loneliness, the convergence of high levels of both co-exposures resulted in extreme values of emotional loneliness, which calls for the same considerations we just described.

The findings from the stratified analyses suggest that people who screen positive for mental health outcomes may respond differently to interventions that address social connections. Future research is required to confirm a weaker response from people with depression—consistent with studies that found a “lower bound” for the ideal number of close friends to avoid depression (Falci & McNeely, 2009; Ueno, 2005)—and whether paradoxical effects are present among people with depression and anxiety (ideally through confirmed diagnosis). Similarly, special attention might be required among people who report anxiety, report a high number of close friends, but are unable to spend time with them.

A recent meta-synthesis examining experiences of loneliness among young people with depression suggests that loneliness and depression

can form a self-reinforcing cycle, in which social withdrawal and difficulties communicating about mental health challenges exacerbate both conditions (Achterbergh et al., 2020), consistent with previous reports (Cacioppo et al., 2006). Past research has shed light on the limits of social contact among people who struggle with existential isolation (Pinel, 2018; Pinel et al., 2017). Interventions may therefore need to move beyond simply increasing social contact, instead supporting individuals in safely disclosing their experiences and helping social networks respond in supportive ways (Achterbergh et al., 2020). This speaks to a need for social connection and social prescribing approaches that are premised on individualized, relational referrals rather than uniform targets and which may be better suited to the heterogeneous patterns observed here than any fixed threshold (Pardede & Kovač, 2023).

Numeric thresholds may appear attractive because they are simple to communicate and easy to monitor, but that simplicity is contingent on a prespecified outcome. Fixed targets also risk obscuring heterogeneity in social needs, such as those found among people who screen positive for mental health. Exploring differential responses based on other determinants of health, like income, employment, gender identity and modality, life stage, and social context is required. Past research suggests that increasing social connection may actually increase loneliness (Card & Delgado-Ron, 2026) and cut-offs could trigger similar responses if particular subgroups are unable to meet these expectations.

An alternative to anchoring guidelines to universal quantitative cutoffs is to emphasize flexible, inclusive, and context-sensitive principles that support meaningful social connection while allowing for variation in how connection is experienced and maintained. This approach is consistent with the Canadian Social Connection Guidelines' co-produced, evidence-informed design principles, which prioritized equity, contextual sensitivity, and feasibility over fixed universal thresholds (Card et al., 2025; Refol et al., 2025), and with social prescribing as their person-centred implementation mechanism that translates these principles into tailored, community-based support.

4.3. Strengths and limitations

Our study has several strengths. The analysis draws on a large and diverse sample spanning all Canadian provinces and three years of data collection, which improves the geographic coverage and temporal post COVID-19 breadth of the findings. The analytic approach also allowed flexible modelling of potentially complex exposure-outcome relations. Notwithstanding, several limitations should also be considered, with an eye toward future directions. First, the measures of social exposure, including the number of close friends and time spent with friends, may not fully capture the quality, reciprocity, or emotional depth of social relationships, which are important dimensions of social connectedness (Pardede & Kovač, 2023). Similarly, it is likely that key thresholds change on the basis of racialization, gender, and other axes of marginalization. Future research will explore these particular effects. Second, restricting the basis functions for time spent with friends was necessary due to the limited range of weekday values, but this constraint may reduce the flexibility of the smooth function and potentially obscure more complex nonlinear patterns. Third, although stratified analyses were conducted for depression and generalized anxiety symptoms, these groups may differ on other unmeasured characteristics (e.g., personality traits, life stressors, or physical health conditions) that could influence both social relationships and loneliness, introducing residual confounding. Given the smaller sample size of certain subgroups, future research should explore and confirm the existence and accuracy of thresholds in these subgroups, as well as the paradoxical effects we mentioned. Fourth, the screening tools used to identify depression (PHQ-2) and generalized anxiety (GAD-2) are brief screening instruments rather than diagnostic assessments, which may result in misclassification of mental health status. Fifth, while the sample includes participants from all Canadian provinces, it may not be fully

representative of the Canadian population (e.g., our sample had a relatively high prevalence of mental health disorders (Stephenson, 2023, p. 75), was skewed toward and older population and was composed predominantly by women). Whereas our findings inform population-level recommendations, the study estimates may not correspond to those of the general population. The cross-sectional nature of the analyses within each wave also limits causal inference and the ability to establish temporal ordering between exposures and outcomes. Finally, loneliness, social connections, and mental health symptoms were self-reported, which may introduce measurement error or reporting bias.

5. Conclusion

Greater benefits were observed at lower levels of social exposure (from zero to three or four friends and from no social contact to a couple of days per week), with diminishing benefits at higher levels beyond these thresholds. However, patterns at higher levels of socialization varied across some groups and should be interpreted cautiously given sparse data and uncertainty about their robustness. These findings suggest that recommendations to increase socialization may be beneficial for most individuals, but the observed thresholds should not be interpreted as universal targets. Taken together, these findings indicate that no single numeric target can adequately capture the complexity of social connection as a determinant of health; rather, the optimal level of social connection is likely context-dependent.

CRedit authorship contribution statement

Jorge Andrés Delgado-Ron: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Heather Orpana:** Writing – review & editing. **Charlotte Roddick:** Writing – review & editing. **Kate Mulligan:** Writing – review & editing. **Elizabeth C. Pinel:** Writing – review & editing. **Peter J. Helm:** Writing – review & editing. **John L. Oliffe:** Writing – review & editing. **Robert J. Coplan:** Writing – review & editing. **Cecilia Benoit:** Writing – review & editing. **Steve Joordens:** Writing – review & editing. **Shayna Skakoon-Sparling:** Writing – review & editing. **Kiffer George Card:** Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Ethics declaration

Written informed consent to take part in the study and to publish the article has been obtained from all participants or their legal representatives. The privacy rights of participants have been observed.

This study was performed in compliance with relevant laws, regulatory frameworks and guidelines where the research took place. This study was approved by the University of Victoria (Approval No. 21-0115) and Simon Fraser University (Approval No. 30000986).

Research data

The data that support the findings of this study are openly available in GitHub at https://github.com/jorgeandr3s/heal/tree/main/cs/cs/public_data.

Ethics in publishing statement

This research presents an accurate account of the work performed, all data presented are accurate and methodologies detailed enough to permit others to replicate the work.

This manuscript represents entirely original works and or if work and/or words of others have been used, that this has been appropriately cited or quoted and permission has been obtained where necessary.

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All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2026.101970>.

Data availability

The data user agreement, data dictionary, and available datasets can be found in the Canadian Alliance for Social Connection and Health website at <https://casch.org/cschs>.

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