Neighbourhood influences on youth mental health and stress levels during the first six months of the COVID-19 pandemic

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Abstract

The impacts of the COVID-19 pandemic on youth mental health and stress levels warrants urgent attention. In Canada, as elsewhere in the world, public health measures in the early stages of the pandemic dramatically transformed the everyday geographies of young people. In the hyper-localisation of everyday life, surrounding neighbourhood features like parks and food-related stores may have provided the only outlets for physical activity, social interaction, and relaxation outside of the home. We examine how health-related behaviours, neighbourhood features, and demographic factors may relate to changes in youth mental health and stress levels during the first six months of the pandemic. A cross-sectional youth-informed online survey was conducted with youth, aged 13-19, in London, Ontario, Canada. Respondents were surveyed about their mental health and stress levels before and during the first six months of the COVID-19 pandemic. From 279 respondents, we identified how age, gender, ethnicity, dietary habits, physical activity levels, and availability of parks, fast food, convenience stores and grocery stores could correlate with mental health and stress levels. Given the role played by public spaces, our work underscores the importance of including youth perspectives in the planning of the public realm which contributes to healthy and thriving communities.

Keywords: mental health; stress; pandemic; youth; food environments; parks

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Background

Beginning December 2019, the novel COVID-19 viral infection spread rapidly internationally, and on March 11, 2020, it was declared a pandemic by the World Health Organization. To reduce the spread of the virus, various countries implemented public health measures such as stay-at-home orders, quarantines, and social/physical distancing. Shifts from in-person schooling to online learning represented a substantial change to the daily routines of children and adolescents (Lee 2020; Zhang et al. 2020). Additionally, the pandemic impacted youth milestones such as school graduation ceremonies, as well as transitioning to postsecondary education or the labour market (Hawke et al. 2020; Nelson Ferguson et al. 2021; Scott et al. 2021). These substantial changes in the lives of youth have led to widespread concerns for their mental wellbeing (Lee 2020; Zhang et al. 2020; Cost et al. 2022). Given the number of developmental milestones that occur in this age group, the pandemic's disruptive impacts could have far-reaching consequences for educational attainment, income, family formation, socialization, and long-term health outcomes. When considering the inequitable distribution of impacts of the pandemic, such as movement restrictions, loss of employment and educational opportunities, and fracturing of social connections, experienced particularly by marginalized populations in Canada and elsewhere, there is concern that youth trajectories after the pandemic could be dependent upon place-related factors (Wilke et al. 2020; Whitley et al. 2021).

Evidence is now shedding light on the impacts of the pandemic on the mental wellbeing of young people both in Canada and around the world. A systematic review of international studies found that the pandemic has had a detrimental impact on youth mental wellbeing outcomes (Nearchou et al. 2020). A survey of adolescents in China found

that more than 1 in 5 adolescents experienced worse symptoms of depression, anxiety, and stress as compared to pre-pandemic (Zhang et al. 2020). In Canada, survey data of clinical and community samples found that youth aged 14 to 28 years old experienced an increase in mental health concerns in the early phases of the pandemic (Hawke et al. 2020). Significant declines in self-reported mental health were also observed during the pandemic compared to 3 months earlier among youth with physical health concerns (Hawke et al. 2021a). Additionally, 51% of Canadian adolescents (aged 12-18) who undertook an online survey met the clinical cut-off for depression and 39% met the cut-off for anxiety during the first stages of the pandemic (Craig et al. 2022).

It is noteworthy that some Canadian adolescents report improvements to their mental wellbeing during the pandemic (Hawke et al. 2020; Nelson Ferguson et al. 2020; Statistics Canada 2021; Cost et al. 2022). For example, Cost et al (2022) found in their survey of research and clinical cohorts, that 20% of adolescents aged 13-18 reported improvements in depression, and 47% reported that depression had worsened for them. During the pandemic, some adolescents may have had more time for rest and relaxation, reflection, and self-care, and may have experienced reduced stress, which might support wellbeing (Hawke et al. 2020; Nelson Ferguson et al. 2021). Yet, research on the association between adolescent mental wellbeing and the COVID-19 pandemic tends to focus on depression and anxiety, while experiences of daily stress are less often considered. It is important to distinguish these measures, as stress levels are deeply personal based on a wide range of drivers related to the surrounding neighbourhood environment, such as access to leisure and socialization opportunities (Ettekal & Agans 2020) as well as greenspaces (Mennis et al. 2018), familial relationships, work, education, or life major changes, like living through a global pandemic. Evidence suggests that Canadian adults

have on average experienced increased stress since the COVID-19 pandemic (Woodruff et al. 2021) and that stress may be more severe among those who are younger (Kowal et al. 2020). Youth living in poverty and non-white youth are considerably more likely to have worse mental health outcomes during the pandemic (Gadermann et al. 2021; White et al. 2021; Whitley et al. 2021). Therefore, research is needed to examine predictors of both improved and worsened mental health, including stress levels, among youth to better inform services and supports as society moves through the phases of the COVID-19 pandemic and to better prepare for future pandemic scenarios.

The pandemic situation resulted in a tightening of daily activity spaces to the immediate area around home (Marwah et al. 2022). This hyper-localization of life to the surrounding neighbourhood amplifies the potential role of place in affecting outcomes from the pandemic. Suburbanization has anecdotally accelerated during the pandemic, with the density and lifestyles of urban areas being viewed as inherently less safe than the open spaces and isolation offered by suburban areas (Biglieri et al. 2020). Understanding the impacts of COVID-19 requires a place-based lens to view how built form, lifestyles, and access to amenities attenuates the impacts from the pandemic on mental health and stress levels, distinguishing the differences between urban and suburban neighbourhood forms (Acuto et al. 2020). Given the automotive dependency of suburban locales in Canada, and youth having limited mobility via cars, we suggest suburbanization is an even more important differentiator of outcomes from the pandemic among this specific subpopulation.

The purpose of our study is to examine the impact of the COVID-19 pandemic on the mental health and stress levels of youth during the first six months of the pandemic in 2020 in a mid-sized Canadian city (London, Ontario), and to assess factors associated with better

and worse mental health and stress levels. Specifically, we seek to address the primary research question: what demographic, behavioural, and neighbourhood environment factors were associated with improvements or declines in self-rated mental health and stress levels among youth in London, Ontario? Additionally, we seek to answer a secondary question: how were neighbourhood environment factors associated with improvements or declines in self-rated young people's mental health and stress levels, accounting for individual-level demographic and behavioural factors?

We conceptualize youth mental health and stress levels in the context of the socio-ecological model which acknowledges the interdependent nature of identity, behaviours, environments, and time (Bronfenbrenner 2005). We account for time by using an outcome variable that represents the change in mental health and stress levels from before and after the introduction of physical distancing measures due to the pandemic. We account for individual-level factors by considering age, gender, ethnicity, diet, and physical activity levels. We account for both social and environmental factors by considering the surrounding neighbourhood context, focusing on the destinations that were available to youth for leisure and socialization during the first six months of the pandemic – restaurants and parks – in the surrounding area, and the level of suburbanization of these areas. All of these variables are widely accepted factors in explaining youth mental health and stress levels (Brown et al. 2021; Fleckney & Bentley, 2021; Mueller et al. 2019; Pascoe et al., 2020; Tillmann et al., 2018). Our study contributes new evidence as to how individual, social, and environmental factors may have influenced youth mental health and stress levels during the pandemic.

We proceed with a description of our study design, the local geographic and pandemic response context of our study area, the measures, and statistical analysis. We

then show the factors associated with changes in mental health and stress levels, discussing the research and policy implications of our findings.

Methodology

Study design

A cross-sectional online survey was conducted from June to September 2020 to gather information on the health and health-related habits of youth in Canada. Our sample was primarily drawn from youth attending secondary schools, however, there was no enrollment-based eligibility criteria applied to our study protocol that would have prevented a home-schooled, elementary school or tertiary-enrolled student from completing the survey if they met the age criteria. All schools in Canada moved to remote-only instruction from March 2020 onwards, and thus respondents to our survey over the summer would have been reflecting on this initial period of school closure (March – June 2020, in line with the Canadian secondary school calendar year). We categorise the survey as 'youth-informed' because we specifically adopted practices to integrate youth perspectives into the research design. The survey was developed in consultation with a diverse group of teenagers on the Human Environments Analysis Laboratory's Youth Advisory Council (HEALYAC). The HEALYAC reviewed the survey items and online functionality, providing feedback that was incorporated into the final version. The inclusion of youth perspectives in research on youth is fundamental to ensuring validity of the research, and to ethically engage with an often-marginalized population group (Arunkumar et al. 2018; Nelson Ferguson et al. 2023).

Survey participants were recruited through social media (the HEALYAC Instagram account and the HEALYAC Facebook and Twitter accounts), members of the HEALYAC, and the social media pages of other youth-serving organizations in Canada. A weblink was

provided, directing potential participants to the online survey. Similar approaches to recruitment have been used to rapidly reach participants during the early phases of the COVID-19 pandemic (Woodruff et al. 2021). The survey took approximately 20 minutes to complete and was available in English and French on the Qualtrics platform. At the start of the survey, participants were provided with a letter outlining study details and eligibility. Participants who could read and write in English or French, aged 13 to 19 years old at the time of the survey, and residing in Canada were eligible to participate in the study. Participants who gave consent were directed to the survey and were eligible to enter a draw for a $250 gift card. The study was approved by The University of Western Ontario's Non-Medical Research Ethics Board.

We report on results only from survey respondents who reported a six-digit postal code within the London, Ontario, Canada region. There were 639 respondents to the survey. We report only on the 279 respondents who reported a valid postal code in the study region and had complete data. The Checklist for Reporting Results of Internet E-Surveys is used to inform the reporting of results (Eysenbach 2004). This checklist is provided as a supplementary file.

Study area

The study area consists of the Middlesex Census Division in Ontario, Canada comprising the local governments of the City of London and Middlesex County. The area is approximately equal distance (~200 km) from Toronto, Ontario, Canada and Detroit, Michigan, United States of America. The 2020 estimated population is 510,738 with 20,502 boys and 20,057 girls aged between 13 to 19 years old (Statistics Canada 2020). The majority of the population is concentrated within the built-up area of the City of London.

A typical mid-size Canadian city, London is characterized by a primary central business district, surrounded by a ring of compact grid-based neighbourhoods, that are further surrounded by another ring of post-World War II superblock developments with major commercial nodes (Hodge and Gordon 2008; City of London 2018). Two branches of the Thames River bisect the region, with many publicly accessible and large greenspaces dispersed throughout the area (Figure 1). Restaurants, convenience stores, and grocery stores are typically limited to commercial areas dispersed throughout the city.

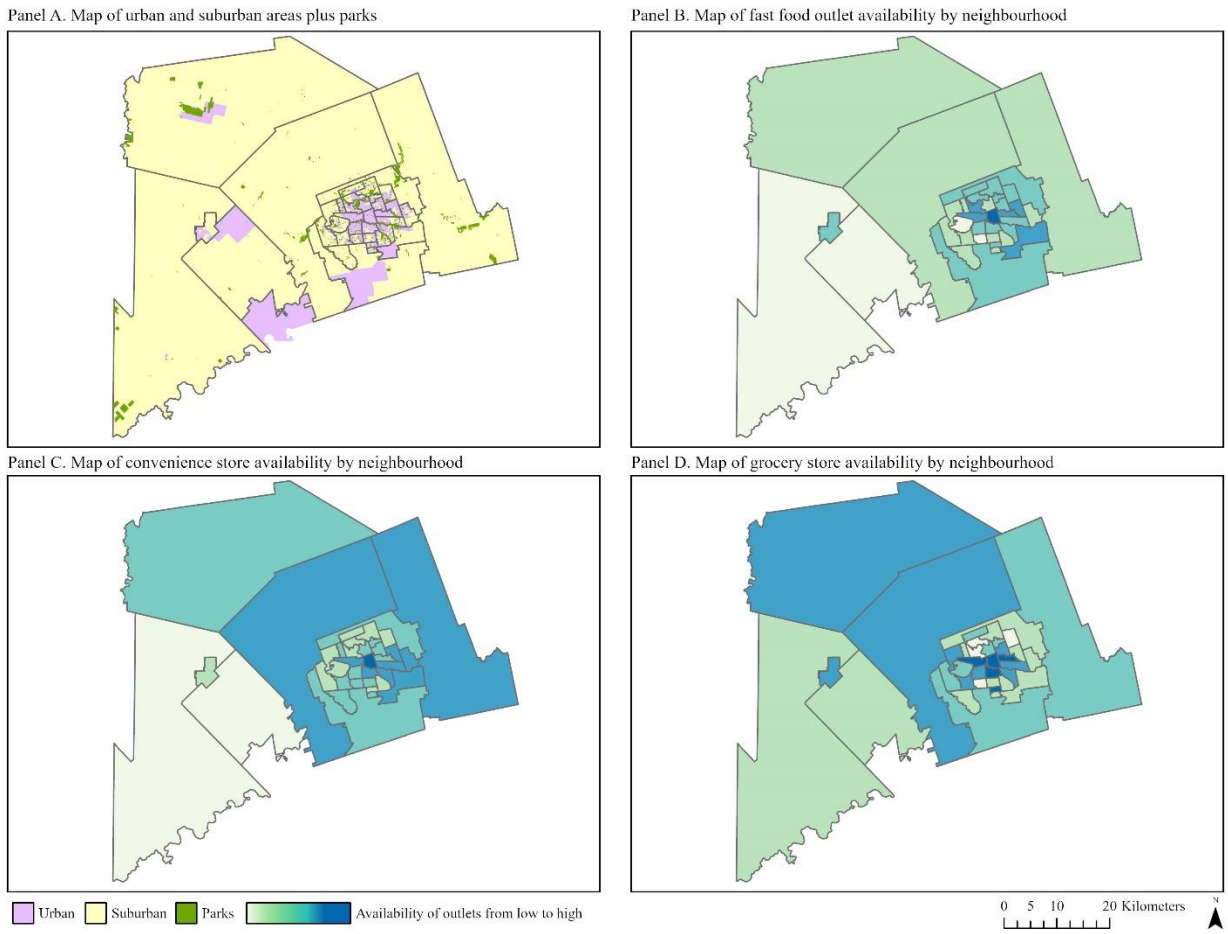

Figure 1. Map of study area and relevant environmental variables

In our study area, public health is managed via the Middlesex-London Health Unit locally, which follows and enforces directives issued by the Province of Ontario and the

Government of Canada. On March 17, 2020, the provincial government announced all schools would move to remote instruction, all non-essential businesses would close, fast-food outlets and restaurants would have to operate via takeout and delivery only, convenience and grocery stores would operate with capacity restrictions, no religious or spiritual services were allowed to occur in-person, and all formal indoor and outdoor recreational programming would be discontinued for the foreseeable future (Nielsen 2021). Certainly, unsanctioned gatherings of people could have occurred during this time period, yet there is no reliable data source on the frequency of these activities. The provincial government later adopted a reopening framework that began to allow outdoor dining at fast food outlets and restaurants, while also encouraging socialization outdoors around June 2020 (*Reopening Ontario Act 2020*). However, remote instruction at elementary, secondary, and postsecondary institutions continued until the end of the school year in June 2020.

Education in Ontario occurs in two different grade-based groups; elementary-level instruction for approximately ages 6 to 13, and secondary-level instruction for approximately ages 13 to 19. Tertiary education typically begins at the age of 18 or 19, lasting 1 to 5 years depending on the degree program and level of study. Therefore, from June to September 2020 while school was not in session, the primary destinations available to youth outside of private residences were open spaces (e.g., parks) and food-based businesses (e.g., fast food outlets, convenience stores, and grocery stores).

Measures

There are two outcome measures considered in our analysis. For *mental health*, participants were asked to recall “prior to physical distancing, how would you rate your mental or emotional health?” with the response options: excellent; very good; good; fair;

poor (Boak et al. 2020). This was dichotomized into (1) excellent/good (excellent; very good; good) and (2) fair/poor. Participants were asked, "since physical distancing (e.g., in the last 30 days), your mental or emotional health has been…" with the responses being: much better; somewhat better; unchanged; somewhat worse; much worse. These two variables were then recoded into a variable that represented the overall change with three categories: (1) better mental health, (2) unchanged mental health, and (3) worse mental health.

For *stress levels*, participants were asked to recall "prior to physical distancing, did you feel that you were under any stress, strain, or pressure?" Response options were: yes, almost more than I could take; yes, a lot; yes, some; yes, a little; not at all. This was dichotomized into (1) high stress (yes, almost more than I could take; yes, a lot) and (2) low stress (yes, some; yes, a little; not at all). Participants were then asked, "since physical distancing (e.g., in the last 30 days), have you experienced stress, strain, or pressure…" with the responses being: much less; somewhat less; unchanged; somewhat more; and, much more. These two variables were then recoded into a variable that represented the overall change with three categories: (1) better stress levels, (2) unchanged stress levels, and (3) worse stress levels.

Participants were asked their age (in years), gender, and ethnicity. Only respondents who identified as boys or girls were included in the analysis due to small numbers of respondents who identified as trans or non-binary or who specified they identified with another gender. Ethnicity was coded into white or non-white because of the small numbers of respondents who identified as South Asian, East Asian, Black, Indigenous, another background, or multiple backgrounds. Approximately 20% of London's population is estimated to be non-white (Statistics Canada 2019).

Participants were also asked about their own perceptions of the change in their eating habits and physical activity levels. For eating habits, participants were asked, “since physical distancing, I am eating…” with the responses being: a lot healthier, a little healthier, about the same, a little unhealthier, and a lot unhealthier. For physical activity levels, participants were asked, “since physical distancing, my daily physical activity levels are…” with the responses being: much higher, a little higher, about the same, a little lower, and much lower. These two variables were recoded into a binary measure of improvement/no change (0) or decline (1).

Participants self-reported the six-digit postal code of their primary residence to enable the creation of variables associated with their local neighbourhood environment, represented as a distance of 1200 metres along the street network from the centroid of the participant’s home postal code. This distance was selected to represent a 15-minute walking area around the home postal code, aligning with healthy cities’ research and practice on defining local neighbourhood environments (Pinna and Murrau 2018; Lennon 2021). This spatial processing was completed using the Network Analyst Toolbox in ArcGIS Pro 2.7 (Esri 2020).

The total area of greenspace in hectares was calculated for each participant. These greenspaces include municipal, provincial, and federal parks, and elementary and secondary school yards.

The number of fast food outlets, convenience stores, and grocery stores were each counted individually. Restaurants with table service were excluded as prior research has found youth do not typically visit these places on their own or with their peers, instead preferring quick service-oriented outlets like fast food outlets and convenience stores (Wray

et al. 2021). Only food-related outlets that were confirmed to be operating during June 2020 were included in these calculations (Gilliland et al. 2021).

The immediate surrounding area of a participant's neighbourhood – based on the Canadian dissemination area statistical geographic unit – was classified as urban or suburban based on the method proposed by Moos and Mendez (2015) that reflects suburban ways of living rather than traditional morphological or historical methods of classification related to suburbanization. The pandemic placed an emphasis on behaviour over built form structure (Biglieri et al. 2020; Marwah et al. 2022), thus necessitating an alternative approach to the classification of suburban and urban neighbourhoods. We constructed this measure, following Moos and Mendez (2015), by determining if the census dissemination area matching the postal code of the participant's home exceeds the census district average for the proportion of households who drive to work, own their home, and inhabit a single-detached dwelling. If so, the participant would be classified as living in a suburban area; all other combinations of these three measures are classified as urban areas (Moos and Mendez 2015; Statistics Canada 2019).

Statistical analysis

Multinomial logistic regression was used to examine the demographic, behavioural, and neighbourhood characteristics that were associated with self-rated mental health and stress levels during the pandemic, with the odds of better and worse as compared to unchanged since physical distancing policies were introduced due to the pandemic. Models were further stratified by suburbanization class. All analyses were completed in R 4.0.4 (R Core Team 2020). The *multinom* function in the *nnet* package was used to complete the multinomial logistic regression analyses (Venables and Ripley 2002). A grouped stepwise

model selection analysis using the *model.sel* function in the *MuMIn* package was used to evaluate how parsimonious the models were in representing only individual-level dependent variables versus environmental-level dependent variables, versus all dependent variables together (Barton 2023). The *pR2* function in the *pscl* package was used to estimate the pseudo-R^2 values of the models via the Craig-Uhler technique (Jackman 2020). The level of significance was set at $p < .05$ for all statistical analyses.

Results

Respondents (n=279) had a median age of 16 years, were more likely to be white, and identify as girls (Table 1). For the outcome measures, 20% reported their mental health got better, 23% reported their mental health went unchanged, and 57% reported their mental health got worse; 42% reported their stress levels got better, 19% reported their stress levels went unchanged, and 39% reported their stress levels got worse. Many respondents reported a slight increase in their perceptions of eating healthier while reporting a slight decrease in physical activity levels. Respondents in suburban areas had greater availability of park space, fast food outlets, and convenience stores while respondents in urban areas had greater availability of grocery stores.

Table 1. Summary of respondents' measures by suburban classification

Variable	Urban, N = 88 [1]	Suburban, N = 191 [1]	Overall, N = 279 [1]
Mental Health Change			
Better	16 (18%)	39 (20%)	55 (20%)
Unchanged	20 (23%)	44 (23%)	64 (23%)
Worse	52 (59%)	108 (57%)	160 (57%)
Stress Levels Change			
Better	35 (40%)	81 (42%)	116 (42%)
Unchanged	18 (20%)	36 (19%)	54 (19%)
Worse	35 (40%)	74 (39%)	109 (39%)
Age (years)			
13	6 (6.8%)	12 (6.3%)	18 (6.5%)
14	12 (14%)	24 (13%)	36 (13%)
15	16 (18%)	35 (18%)	51 (18%)
16	15 (17%)	36 (19%)	51 (18%)
17	20 (23%)	43 (23%)	63 (23%)
18	16 (18%)	31 (16%)	47 (17%)
19	3 (3.4%)	10 (5.2%)	13 (4.7%)
Ethnicity			
Non-white	32 (36%)	54 (28%)	86 (31%)
White	56 (64%)	137 (72%)	193 (69%)
Gender			
Girls	69 (78%)	145 (76%)	214 (77%)
Boys	19 (22%)	46 (24%)	65 (23%)
Eating Habits Change			
A lot healthier	7 (8.0%)	14 (7.3%)	21 (7.5%)
A little healthier	18 (20%)	40 (21%)	58 (21%)
About the same	27 (31%)	68 (36%)	95 (34%)
A little unhealthier	26 (30%)	55 (29%)	81 (29%)
A lot unhealthier	10 (11%)	14 (7.3%)	24 (8.6%)
Physical Activity Change			
Much higher	10 (11%)	33 (17%)	43 (15%)
A little higher	19 (22%)	44 (23%)	63 (23%)
About the same	15 (17%)	28 (15%)	43 (15%)
A little lower	19 (22%)	32 (17%)	51 (18%)
Much lower	25 (28%)	54 (28%)	79 (28%)
Park area (hectares) nearby	38 (30, 56)	41 (31, 66)	38 (28, 52)
# Fast food outlets nearby	6 (2, 10)	10 (7, 19)	3 (1, 8)
# Convenience stores nearby	3 (1, 6)	7 (5, 9)	2 (1, 4)
# Grocery stores nearby	2 (0, 8)	1 (0, 6)	1 (0, 8)

[1] n (%); Median (IQR)

Mental health

Respondents with better mental health compared to unchanged mental health were more likely to be non-white and girls (Table 2). Respondents with worse mental health compared to unchanged were more likely girls, and more likely to have a negative change in their eating habits. Among urban respondents, for every year older the respondent was 1.68 times more likely to have better mental health. Meanwhile, urban respondents with a negative change in their eating habits were 6.83 times more likely to have worse mental health. Furthermore, for every one more fast food outlet nearby, urban respondents were 6% less likely to have worse mental health compared to unchanged. Turning to suburban respondents, boys were less likely to have better mental health. For every one more fast food outlet nearby, suburban respondents were 18% more likely to have better mental health, while for every one more convenience store nearby, these respondents were 24% less likely to have better mental health. Suburban respondents with a decline in their physical activity levels were 2.8 times more likely to have worse mental health, and for every one more convenience store nearby, 21% less likely to have worse mental health.

Table 2. Summary of models related to change in mental health by suburbanization classification

Variable	All [1]		Urban [1]		Suburban [1]	
	Better	***Worse***	***Better***	***Worse***	***Better***	***Worse***
Age (years)	1.06 (0.83, 1.34)	1.17 (0.96, 1.43)	**1.68 (1.03, 2.75)**	1.44 (0.98, 2.11)	0.94 (0.70, 1.26)	1.09 (0.85, 1.39)
Ethnicity, ref. Non-White	**0.41 (0.18, 0.92)**	0.87 (0.42, 1.80)	0.38 (0.08, 1.88)	1.28 (0.32, 5.13)	0.43 (0.15, 1.20)	0.82 (0.34, 2.00)
Gender, ref. Girls	**0.27 (0.11, 0.67)**	**0.39 (0.20, 0.78)**	0.39 (0.07, 2.29)	0.29 (0.07, 1.12)	**0.26 (0.08, 0.78)**	0.47 (0.20, 1.09)
Eating habits decline	1.44 (0.56, 3.69)	**3.15 (1.47, 6.73)**	6.08 (0.89, 41.5)	**6.83 (1.39, 33.6)**	0.76 (0.24, 2.43)	2.11 (0.85, 5.24)
Physical activity decline	0.99 (0.43, 2.29)	1.77 (0.90, 3.48)	0.31 (0.05, 1.81)	0.89 (0.23, 3.45)	1.50 (0.52, 4.32)	**2.80 (1.19, 6.60)**
Park area (ha) nearby	0.99 (0.98, 1.01)	1.01 (0.99, 1.02)	0.98 (0.95, 1.01)	1.00 (0.98, 1.02)	1.00 (0.98, 1.01)	1.00 (0.99, 1.02)
# Fast food outlets nearby	1.01 (0.95, 1.06)	0.98 (0.93, 1.02)	0.96 (0.89, 1.03)	**0.94 (0.89, 1.00)**	**1.18 (1.01, 1.39)**	1.11 (0.95, 1.28)
# Convenience stores nearby	0.93 (0.81, 1.07)	0.97 (0.86, 1.09)	1.03 (0.81, 1.29)	1.07 (0.87, 1.30)	**0.76 (0.59, 0.98)**	**0.79 (0.64, 0.98)**
# Grocery stores nearby	0.99 (0.75, 1.32)	1.15 (0.90, 1.46)	1.19 (0.77, 1.85)	1.03 (0.71, 1.51)	0.69 (0.41, 1.15)	1.13 (0.76, 1.68)
Model diagnostics	N = 279 R^2 = 0.20		N = 88 R^2 = 0.39		N = 191 R^2 = 0.23	

[1] exp(β) Odds Ratio (95% Confidence Interval), Better and Worse as compared to Unchanged; ***p* < .05 bolded**

The total park space available nearby and the number of grocery stores nearby did not significantly affect the change in mental health from before the pandemic to the time of the survey across any of the models.

Stress levels

Demographic and behavioural changes did not significantly affect the change in stress levels from before the pandemic to time of the survey across any of the models (Table 3). There were no significant predictors in the model using all respondents. Urban respondents were 6% less likely to have worse (higher) stress levels per one more fast food outlet nearby. However, suburban respondents were 26% more likely to have better (lower) stress levels per one more fast food outlet nearby, and 27% less likely to have better (lower)

stress levels per one more convenience store nearby. Moreover, these respondents were 24% more likely to have worse (higher) stress levels per one more fast food outlet nearby.

Table 3. Summary of models related to change in stress levels by suburbanization classification

Variable	All [1]		Urban [1]		Suburban [1]	
	Better	***Worse***	***Better***	***Worse***	***Better***	***Worse***
Age (years)	0.95 (0.77, 1.17)	0.95 (0.77, 1.18)	1.08 (0.74, 1.59)	1.07 (0.72, 1.60)	0.91 (0.70, 1.19)	0.92 (0.70, 1.21)
Ethnicity, ref. Non-White	1.02 (0.49, 2.12)	0.77 (0.37, 1.61)	0.89 (0.22, 3.56)	0.53 (0.13, 2.23)	1.00 (0.40, 2.51)	0.77 (0.31, 1.95)
Gender, ref. Girls	0.60 (0.28, 1.26)	0.54 (0.25, 1.16)	0.54 (0.13, 2.25)	0.61 (0.13, 2.74)	0.70 (0.28, 1.76)	0.60 (0.23, 1.54)
Eating habits decline	0.81 (0.39, 1.72)	1.26 (0.60, 2.65)	0.56 (0.14, 2.18)	1.06 (0.26, 4.25)	0.81 (0.32, 2.08)	1.15 (0.45, 2.94)
Physical activity decline	0.74 (0.36, 1.51)	1.06 (0.51, 2.18)	1.15 (0.27, 4.80)	2.66 (0.62, 11.5)	0.74 (0.31, 1.81)	0.97 (0.39, 2.37)
Park area (ha) nearby	1.00 (0.98, 1.01)	1.01 (1.00, 1.02)	0.98 (0.96, 1.01)	1.00 (0.98, 1.03)	1.00 (0.98, 1.01)	1.01 (0.99, 1.02
# Fast food outlets nearby	1.00 (0.95, 1.05)	0.98 (0.94, 1.03)	0.96 (0.90, 1.02)	**0.94 (0.87, 1.00)**	**1.26 (1.04, 1.54)**	**1.24 (1.02, 1.51)**
# Convenience stores nearby	0.95 (0.84, 1.07)	1.01 (0.89, 1.14)	1.02 (0.84, 1.24)	1.13 (0.91, 1.41)	**0.73 (0.57, 0.93)**	0.80 (0.63, 1.02)
# Grocery stores nearby	1.02 (0.80, 1.30)	0.99 (0.77, 1.26)	0.85 (0.59, 1.23)	0.68 (0.45, 1.04)	0.86 (0.55, 1.33)	0.93 (0.61, 1.43)
Model diagnostics	N = 279 R^2 = 0.07		N = 88 R^2 = 0.24		N = 191 R^2 = 0.10	

[1] exp(β) Odds Ratio (95% Confidence Interval) Better and Worse as compared to Unchanged; ***p* < .05 bolded**

Grouped stepwise model evaluation

We undertook a stepwise model evaluation approach to compare how parsimonious models were when only including dependent variables representing individual-level factors such as age, ethnicity, gender, eating habits, and physical activity versus those representing environmental-level factors such as park area, number of fast food outlets, number of convenience stores, and number of grocery stores. Results from all models included in this analysis are found in the Supplementary Files. For the mental health outcome, models with just individual-level dependent variables were the most parsimonious for all groups of

participants (Table 4). For the stress outcome, models with just environmental-level dependent variables were the most parsimonious for all groups of participants.

Table 4. Summary of grouped stepwise model evaluation results

Rank[a]	Variable Set	Pseudo-R^2	Log-Likelihood	AIC	Δ AIC	∑ Weight
Mental Health, All						
1	Individual	0.17	-250.40	525.97	-	0.99
2	Combined	0.20	-246. 19	535.64	9.67	0.01
3	Environmental	0.03	-269.19	559.21	33.24	0.00
Mental Health, Urban						
1	Individual	0.30	-71.24	170.64	-	0.99
2	Environmental	0.10	-80.43	183.08	13.07	0.01
3	Combined	0.39	-66.71	185.95	15.31	0.00
Mental Health, Suburban						
1	Individual	0.16	-174.21	374.17	-	0.91
2	Combined	0.23	-167.05	379.04	4.87	0.08
3	Environmental	0.07	-181.77	384.76	10.58	0.01
Stress Levels, All						
1	Environmental	0.03	-288.58	597.99	-	0.89
2	Individual	0.04	-288.55	602.28	4.29	0.11
3	Combined	0.07	-283.92	611.09	13.11	0.00
Stress Levels, Urban						
1	Environmental	0.17	-86.12	195.09	-	0.99
2	Individual	0.07	-90.20	208.56	13.47	0.01
3	Combined	0.24	-82.64	217.82	22.73	0.00
Stress Levels, Suburban						
1	Environmental	0.08	-193.05	407.32	-	0.99
2	Individual	0.03	-197.51	420.78	13.46	0.01
3	Combined	0.10	-190.88	426.70	19.38	0.00

[a] *The rank represents the most parsimonious (1) to least parsimonious model in each set of outcomes and suburbanization classifications*

Discussion

The majority of youth participants reported their mental health worsened during the early phases of the pandemic. However, approximately 1 in 5 youth reported improved mental health. This was consistent across urban and suburban youth. Our finding

corresponds to the findings of Cost et al. (2022) who found in their sample of Canadian adolescents aged 13 to 18 years old, in research and clinical cohorts, that 20% reported improvements in depression, 14% reported improvements in anxiety, and 11% reported improvements in both irritability and attention; although a greater proportion of the sample reported declines in overall mental health. Additionally, evidence from the United Kingdom indicates the impact of COVID-19 on young people's mental health is not uniform; increases in indicators of poor mental health have been found since the pandemic, but some children and adolescents report feeling happier (Ford, John, and Gunnell 2021). Experiences of stress were divided among respondents in our study; with large groups of individuals reporting better and worse stress levels.

Individual-level factors were more parsimonious in representing the observed change in mental health, while environmental factors were more parsimonious in representing the observed change in stress levels. We hypothesize these differences could be from the greater role played by gender, diet, and physical activity in affecting mental health as compared to stress levels. Inversely, stress levels may be more easily regulated by youth through engagement in leisure and social activities that are supported by surrounding environmental features like restaurants, convenience stores, or parks. The potential mechanisms of these hypothesized relationships should be the subject of future research.

Gender-based differences in the impact of the pandemic on mental health are concerning, with girls pre-pandemic tending to fair worse in terms of mental health (De Looze et al. 2018). Our finding that girls overall are more likely to report changes in self-rated mental health are similar to other studies finding that girls reported poorer mental health outcomes than their boy peers, and had wider variability than boys in outcomes

reported from the pandemic (Hawke et al. 2021b; Magson et al. 2021; Craig et al. 2022). Moreover, the gendered assumptions of masculine and feminine behaviours among youth may result in a reporting bias between girls and boys related to their mental health (Landstedt et al. 2009). However, in adjusted models there were no significant differences observed between urban girls and boys in terms of changes to mental health, thus suggesting that geographic context matters in the gendered patterning of mental health during the pandemic. Boys living in suburban locations had a lower chance compared to girls of having better mental health. Given boys are more likely to derive social connectedness from school as compared to girls (Preston & Rew 2021), the loss of their social networks at school may have resulted in boys in more suburban locations feeling more isolated than their urban peers, who are likely in closer proximity at home to their friends from school.

Those who perceived a decline in healthful eating habits over the course of the pandemic were more likely to have worse mental health. Declines in eating habits and poorer mental health are known to be moderately associated with each other among youth, with consumption of fast food and convenience-related purchases often being used as a coping mechanism (Collins et al. 2022). Isolation during the pandemic may have resulted in greater stress eating and snacking throughout the day with the disruption in daily routines. However, we did not observe this effect among suburban dwelling youth compared to urban dwelling youth. In reviewing the differences in effects related to fast food and convenience outlets, urban youth with access to more fast food outlets were slightly less likely to have worse mental health compared to those with unchanged mental health. Suburban youth though were more likely to have better mental health with the more fast-food outlets nearby, as well as, less likely to have better or worse mental health as compared to unchanged with

the more convenience outlets nearby. Given suburban youth that reported a decline in physical activity levels were more likely to have worse mental health, it may be that these youth spent more of their time within the home than outside of it, and thereby were less likely to visit amenities within their local neighbourhood.

Research in a Canadian context has shown youth routinely make independent visits and purchases at fast food and convenience outlets near their home (He, Tucker, Gilliland, et al. 2012; He, Tucker, Irwin, et al. 2012). Fast food and convenience outlets may provide 'third places' outside of home and school for youth to gather and build social cohesion. Third places are spaces outside of home, school, or work where chance and planned social interactions occur, and especially in the North American context are more often privately owned and operated than part of the public realm (Oldenburg and Brissett 1982; Lofland 1989; Mehta and Bosson 2010; Oldenburg 2013). Suburban youth have more fast-food outlets available to them within 1200 metres of their home, as compared to urban youth. We expect this may explain why the correlation of fast food outlet presence with change in mental health and stress levels is comparatively stronger than the correlation observed among urban youth. Among suburban dwelling youth, fast food outlets may have provided a social destination rather than stress-relieving destination, with visits occurring less frequently throughout the week, but with friends as a social outing. We suspect that for youth in urban neighbourhoods, outlets provided a daily destination outside of home for respite from the monotony of home life caused by the pandemic. The functional role of these third places is supported by the finding that urban-dwelling youth were less likely to have worse stress levels with more fast-food outlets nearby. Suburban youth were more likely to have both better or worse stress levels as compared to those with unchanged stress levels with the greater number of fast-food outlets nearby. This dual association could be the result

of another factor not observed in our analysis such as home or school-based stressors intersecting with higher availability of fast-food outlets nearby. Youth with improved stress levels could be visiting fast food outlets to socialize and relax, while youth with worse stress levels could be visiting these places as a coping technique for stress.

Suburban youth have more convenience outlets available to them within 1200 metres of their home, as compared to urban youth. The effects observed for convenience stores in models of mental health and stress levels could be explained by their function as a regular destination within daily life. These regular visits to the convenience store may have provided a routine to daily life, and thereby did not greatly improve or harm mental health and stress levels, instead merely bringing stability to daily life as compared to pre-pandemic. Fast food restaurants had to pivot to takeout, delivery, and outdoor eating models while convenience store operations were relatively unaffected from public health measures. In North American suburbia like London, convenience stores are often located in small auto-oriented commercial plazas or with gas stations in proximity to residential uses. The greater number of these outlets nearby could be a proxy for another unaccounted variable of the neighbourhood's built form.

Strengths and limitations

This study provides evidence and early insights into how the pandemic was impacting youth in its early phases, but has some limitations that should be considered. First, this was a cross-sectional survey with retrospective reports of pre-pandemic mental health and stress levels, which may be subject to recall bias. Second, online survey administration and recruitment means that those without internet access may not have been reached. Third, the sample was based on convenience sampling of those residing within London-Middlesex

and is not representative of the broader Canadian youth population or representative of all levels of youth education given the survey's design. Fourth, we did not account for additional socioeconomic measures, such as household income or multiple deprivation, derived from the Canadian census as this information was last collected in 2016 years prior to the pandemic, and the nature of the COVID-19 pandemic regulations had economic impacts that may not be captured through these data.

Despite these limitations, this study has several strengths. First, the survey timing matches the first wave of the COVID-19 pandemic in Canada which corresponds with the strictest forms of movement restrictions, that would have substantially altered daily activity spaces. Second, the questions used in the survey instruments were informed and tested by youth, which supports the validity of our findings. Third, this study included assessments of improvement in mental health and stress levels. This survey design allowed for a more nuanced assessment of youth mental health and stress levels during the first six months of the pandemic. Fourth, a measure of stress was included, which remains an understudied aspect of youth wellbeing. Feeling under stress and pressure is likely to fluctuate as daily routines and activities change, including past and anticipated changes to school delivery. Fifth, this study made use of high-quality information about the accessibility to parks, fast-food outlets, convenience stores, and grocery stores using network-based spatial analysis, which provides a considerable improvement over Euclidean buffer or container-based approaches.

Future research

Our study only examined experiences during the early phases of the pandemic (after school closures), and experiences may change as the pandemic continued, which could

pose long-term effects on youth. Mental health tends to get worse the longer children experience social and economic disadvantage (Seabrook and Avison 2012), therefore, studies accounting for these predictors using temporally comparable data and longitudinal designs are needed (Lee 2020; Magson et al. 2021). This study was conducted during the summer months, when school was out of session and the weather was warm. Further studies are needed that examine the impacts of COVID-19 during different timeframes and seasons to see if results vary.

Given the lack of observed effects from parks in our models, but meaningful effects from 'third places' that were open to visit, future research should gather data on the destinations youth visit and engage with on a regular basis, during and after the pandemic. There remains a dearth of evidence about these locational behaviours in adolescents, and the accompanying interventions that would drive engagement with these spaces, compared to young children, adults, and older adults (Wray et al. 2020). Moreover, Hawke et al. (2021b) found youth living in large urban and suburban communities had greater worries about COVID-19 than youth living in smaller rural communities. Unpacking the contextual and perceptual differences between these environments is crucial to understanding how place affects youth health outcomes from the pandemic. Little is known about what destinations youth visit and with whom, especially during the pandemic, hampering researchers in establishing if local neighbourhoods provide valuable gathering space outside of home and school.

The role of digital platform use among youth, as well as during the pandemic out of necessity, may have altered how youth interact with surrounding neighbourhood amenities, particularly as it relates to food-based businesses. These platforms may uncouple pre-

existing concepts of spatial proximity by, for example, making food-based businesses within a reasonable driving distance all reasonably accessible for home delivery via a digital ordering platform. Future research should consider how these platforms have altered exploration of, and interactions with, public spaces.

Policy implications

Our findings suggest local policymakers and practitioners could play a role in addressing youth mental health and stress levels through the following actions:

- Directly incorporating youth perspectives in the planning and programming of public spaces.
- Emulating in public spaces the socialization opportunities, which often include food, drinks and leisure together, that are provided by private 'third places' outside of home and school.
- Providing more tailored social and cultural programming to youth at a local level, as is done for younger children and older adult populations.
- Consider how digital platforms showcase food-oriented amenities that are available in local neighbourhoods, and modify interactions with the public realm to reflect near ubiquitous access to smartphones among youth.

While the public realm provided crucial space for recreation, socialization, and physical activity during the pandemic (Honey-Rosés et al. 2020; Wray, Fleming, and Gilliland 2020), our findings should prompt further reflection on who was best served by these spaces, and how cities should be changed to better meet the needs of youth populations. The unobserved impact of parks, yet significant impact of privatized third places like fast-food outlets and convenience stores, suggest these spaces may provide more to youth than

traditional public space managed by local governments. Our research suggests that, since the pandemic, there have been declines in mental health and stress levels among many Canadian youth, especially among girls and older youth; however, for some, mental health and stress levels have improved. Differences remain between urban and suburban-based youth in their experiences and outcomes from the pandemic, highlighting the need to continually reflect upon neighbourhood-level contextual differences in healthy communities' research and practice. Our findings highlight the need for future research and policy decisions to consider improvements, as well as declines, to youth mental health and stress levels as we move through the COVID-19 pandemic and plan for future pandemic scenarios.

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The authors report there are no competing interests to declare.

Geolocation Information

This manuscript includes the geographic location of London, Ontario, Canada. The manuscript has global relevance.

Biographical Note

The Human Environments Analysis Laboratory is a state-of-the-art, multi-disciplinary research and training environment at Western University in London, Ontario, Canada. The lab specializes in the production, evaluation, synthesis, dissemination and mobilization of evidence needed for the development of effective policies, programs and professional practice aimed at creating healthy and vibrant communities.

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Checklist for Reporting Results of Internet E-Surveys (CHERRIES)

Item Category	Checklist Item	Explanation	Reporting Results
Design	Describe survey design	Describe target population, sample frame. Is the sample a convenience sample? (In "open" surveys this is most likely.)	Convenience sample
IRB (Institutional Review Board) approval and informed consent process	IRB approval	Mention whether the study has been approved by an IRB.	Approval was sought from the affiliated universities ethics committees.
	Informed consent	Describe the informed consent process. Where were the participants told the length of time of the survey, which data were stored and where and for how long, who the investigator was, and the purpose of the study?	On the recruitment material, a web link was provided to direct potential participants to the e-survey. At the start of the survey, participants were provided with a Letter of Information outlining study details (e.g., purpose, length of time to complete, how and where data is stored and for how long, rights of the participant, incentives, investigator information) and consent was implied if teens agreed to participate.
	Data protection	If any personal information was collected or stored, describe what mechanisms were used to protect unauthorized access.	The survey platform (Qualtrics) uses encryption processes with restricted access authorization to protect all data collected. Only the research team can access the password-protected platform.
Development and pre-testing	Development and testing	State how the survey was developed, including whether the usability and technical functionality of the electronic questionnaire had been tested before fielding the questionnaire.	The survey was developed by researchers from various disciplines (i.e., health geography, health science, epidemiology and biostatistics). Prior to fielding the e-survey, it was piloted for usability and technical functionality by the research team and affiliated Youth Advisory Council (HEALYAC) members.
Recruitment process and description of the sample having access to the questionnaire	Open survey versus closed survey	An "open survey" is a survey open for each visitor of a site, while a closed survey is only open to a sample which the investigator knows (password-protected survey).	Open survey

	Contact mode	Indicate whether or not the initial contact with the potential participants was made on the Internet. (Investigators may also send out questionnaires by mail and allow for Web-based data entry.)	Internet (i.e., social media)
	Advertising the survey	How/where was the survey announced or advertised? Some examples are offline media (newspapers), or online (mailing lists – If yes, which ones?) or banner ads (Where were these banner ads posted and what did they look like?). It is important to know the wording of the announcement as it will heavily influence who chooses to participate. Ideally the survey announcement should be published as an appendix.	The affiliated Youth Advisory Council (HEALYAC) members promoted the e-survey through their social media platforms and social networks. Recruitment materials were also sent to various Youth Advisory Councils across Canada to share across their social networks.
Survey administration	Web/E-mail	State the type of e-survey (eg, one posted on a Web site, or one sent out through e-mail). If it is an e-mail survey, were the responses entered manually into a database, or was there an automatic method for capturing responses?	Web site
	Context	Describe the Web site (for mailing list/newsgroup) in which the survey was posted. What is the Web site about, who is visiting it, what are visitors normally looking for? Discuss to what degree the content of the Web site could pre-select the sample or influence the results. For example, a survey about vaccination on a anti-immunization Web site will have different results from a Web survey conducted on a government Web site	A Web site was created that directed participants to the Letter of Information detailing the study.
	Mandatory/voluntary	Was it a mandatory survey to be filled in by every visitor who wanted to enter the Web site, or was it a voluntary survey?	Voluntary
	Incentives	Were any incentives offered (eg, monetary, prizes, or non-monetary incentives such as an offer to provide the survey results)?	After every 800 completed surveys, there was a draw for a $250 gift card.
	Time/Date	In what timeframe were the data collected?	Data were collected between June 2020 - September 2020.
	Randomization of items or questionnaires	To prevent biases items can be randomized or alternated.	To avoid conceptual complexity, randomization was not used as order was important for referencing time before and after social distancing measures.

	Adaptive questioning	Use adaptive questioning (certain items, or only conditionally displayed based on responses to other items) to reduce number and complexity of the questions.	To reduce the number and complexity of questions, various skip patterns were put in place, directing participants to questions based on their previous responses.
	Number of Items	What was the number of questionnaire items per page? The number of items is an important factor for the completion rate.	The number of questionnaire items per page ranged from one to seven.
	Number of screens (pages)	Over how many pages was the questionnaire distributed? The number of items is an important factor for the completion rate.	The questionnaire was 39 pages in length with six of those pages designated to the Letter of Information, eligibility, consent, incentive, and participation in future research.
	Completeness check	It is technically possible to do consistency or completeness checks before the questionnaire is submitted. Was this done, and if "yes", how (usually JAVAScript)? An alternative is to check for completeness after the questionnaire has been submitted (and highlight mandatory items). If this has been done, it should be reported. All items should provide a non-response option such as "not applicable" or "rather not say", and selection of one response option should be enforced.	Not applicable
	Review step	State whether respondents were able to review and change their answers (eg, through a Back button or a Review step which displays a summary of the responses and asks the respondents if they are correct).	Participants were able to use the Back button to change their answers. A Review step was not utilized.
Response Rates	Unique site visitor	If you provide view rates or participation rates, you need to define how you determined a unique visitor. There are different techniques available, based on IP addresses or cookies or both.	Not determined
	View rate (Ratio of unique survey visitors/unique site visitors)	Requires counting unique visitors to the first page of the survey, divided by the number of unique site visitors (not page views!). It is not unusual to have view rates of less than 0.1 % if the survey is voluntary.	Not determined

	Participation rate (Ratio of unique visitors who agreed to participate/unique first survey page visitors)	Count the unique number of people who filled in the first survey page (or agreed to participate, for example by checking a checkbox), divided by visitors who visit the first page of the survey (or the informed consents page, if present). This can also be called “recruitment” rate.	Not determined
	Completion rate (Ratio of users who finished the survey/users who agreed to participate)	The number of people submitting the last questionnaire page, divided by the number of people who agreed to participate (or submitted the first survey page). This is only relevant if there is a separate “informed consent” page or if the survey goes over several pages. This is a measure for attrition. Note that “completion” can involve leaving questionnaire items blank. This is not a measure for how completely questionnaires were filled in. (If you need a measure for this, use the word “completeness rate”.)	851 (see 28,31, & 32)/ 1179 eligible participants who completed the first survey page (consent page) after duplicate [IP address AND age] removed as well as out of Canada participants 72%
Preventing multiple entries from the same individual	Cookies used	Indicate whether cookies were used to assign a unique user identifier to each client computer. If so, mention the page on which the cookie was set and read, and how long the cookie was valid. Were duplicate entries avoided by preventing users access to the survey twice; or were duplicate database entries having the same user ID eliminated before analysis? In the latter case, which entries were kept for analysis (eg, the first entry or the most recent)?	None used
	IP check	Indicate whether the IP address of the client computer was used to identify potential duplicate entries from the same user. If so, mention the period of time for which no two entries from the same IP address were allowed (eg, 24 hours). Were duplicate entries avoided by preventing users with the same IP address access to the survey twice; or were duplicate database entries having the same IP address within a given period of time eliminated before analysis? If the latter, which entries were kept for analysis (eg, the first entry or the most recent)?	IP addresses were checked for duplicates after survey entries were removed based on incompleteness or atypical timestamp (see 31 and 32). Because individuals in the same household could complete the survey on the same device, a variable of IP address and age was created. Where age AND IP address were identical the entry with the highest Progress (proportion of the questionnaire viewed) value was kept for analysis, or if these were equal the first entry was kept.

Analysis	Log file analysis	Indicate whether other techniques to analyze the log file for identification of multiple entries were used. If so, please describe.	None used
	Registration	In “closed” (non-open) surveys, users need to login first and it is easier to prevent duplicate entries from the same user. Describe how this was done. For example, was the survey never displayed a second time once the user had filled it in, or was the username stored together with the survey results and later eliminated? If the latter, which entries were kept for analysis (eg, the first entry or the most recent)?	Not applicable
	Handling of incomplete questionnaires	Were only completed questionnaires analyzed? Were questionnaires which terminated early (where, for example, users did not go through all questionnaire pages) also analyzed?	Survey which were only viewed to questions regarding demographics/living situation but did not progress through the questionnaire to any questions regarding health outcomes/behaviours (Progress <42%).
	Questionnaires submitted with an atypical timestamp	Some investigators may measure the time people needed to fill in a questionnaire and exclude questionnaires that were submitted too soon. Specify the timeframe that was used as a cut-off point, and describe how this point was determined.	Surveys which were competed in 3 minutes or less (180 seconds) were not included in analysis (Duration =<180).