

## Article

# Smartphone Use and Mental Health among Youth: It Is Time to Develop Smartphone-Specific Screen Time Guidelines

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**Abstract:** Smartphone use has become increasingly popular and almost all age cohorts engage in smartphone usage for a wide variety of activities. This study aims to investigate the relationship between high smartphone use and mental health among youth and in two urban centres in Canada. This study is part of the Smart Platform, a digital epidemiological and citizen science initiative. Citizen scientists provided all data via their own smartphones using a custom-built smartphone application. The baseline questionnaire included measures of smartphone screen time behaviours (internet use, gaming, and texting), demographic characteristics, and health outcomes including anxiety, suicide ideation, feelings of depression, and self-rated health. Binary regression models determined the relationship between smartphone use and mental health measures. Among the 437 participants (13–21 years old), 71.2% reported high total smartphones use during a typical week (5 weekdays and 2 weekend days). High weekday and high weekly total smartphone use were associated with an almost two times higher risk of screening positive for anxiety, while high weekend gaming and high total smartphone use were associated with an almost three times higher risk of suicide ideation. Moreover, high weekend total smartphone use was also associated with an almost three times higher risk of poor self-rated mental health. Our findings suggest that high smartphone use's association with mental health varies by type of activity as well as type of day (weekday/weekend day). Smartphone usage among youth has become near universal and it is important to factor in variations in smartphone usage's impact on mental health in developing smartphone-specific screen time guidelines by taking into context both type of activities, as well as type of day (weekday/weekend day).

**Keywords:** youth health; citizen science; mental health; smartphone use; social media; screen time; digital health; sedentary behaviour



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## 1. Introduction

Worldwide, there are over 6 billion people that have smartphone data plans and it is projected that this will grow to over 7.5 billion by 2026 [1]. Smartphone devices have the same capabilities of a fully functioning computer, in the convenient size of a wireless hand-held device. Capitalising on that convenience, youth reportedly have access to smartphones more so than any other electronic device. A study in the United States showed that only 88% of youth reported having access to a computer, while 95% reported having access to a smartphone [2]. Furthermore, reduced access to a computer was associated with lower household income; whereas smartphone access appeared to be universal among families regardless of gender, race, ethnicity, and socioeconomic background [2]. With the high rate of smartphone market penetration across the globe and across sub-groups of youth [1,2], it is critical to understand the relationship between smartphone usage and population health among youth.

In recent years there has been emerging research on smartphones' association with health among youth, with most evidence focused on social media use [3]. However,

smartphones have more connectivity possibilities and advances than any other form of screen time electronic devices. For example, individuals can engage in activities such as watching television, gaming, and communications such as texting all on the same device. There is a lack of research that addresses a broad understanding of smartphone usage (i.e., all of internet, gaming, and texting use) and whether it is related to population health and wellbeing.

The research that addresses the relationship between excessive use of electronic devices and negative health outcomes is often understood through screen time research. Excessive screen time has been associated with poor self-esteem, depression, anxiety, suicidal thoughts in several studies [4,5]. However, a systematic review has argued that there is insufficient evidence for associations between screen time and health issues such as anxiety, poor self-esteem, poor cognition, poor sleep outcomes, or suicidal ideation [6]. In contrast, other evidence suggests that youth who engaged in screen time behaviours (e.g., playing games or internet use) involving academic activities had better mental wellbeing than youth who spent less time on those activities [7].

Longitudinal research shows a consistent relationship between screen time and health behaviours among youth and their mental health. Gunnell and colleagues (2016) analysed the relationship between physical activity, screen time, anxiety, and depression over a period of 11 years among Canadian participants from age 10 to 21 years. The authors found that, over time, an increase in anxiety and depression were associated with an increase in screen time use [8].

Evidence from a review paper [9] reports that smartphone use is associated with adverse mental health outcomes. Additionally, a meta-analytic review [10] specifically reported that smartphone use is associated with stress and anxiety. A systematic review also confirms associations between problematic smartphone use and depression severity [11]. Another study confirms associations between problematic smartphone use and negative psychological wellbeing in general [12]. Horwood and Anglim assessed whether there are differences in the association between problematic smartphone usage behaviours and wellbeing. They found that when smartphone use was for entertainment purposes (i.e., used to relax, escape, pass time) it was correlated with lower wellbeing while smartphone use for communication purposes (i.e., texting, calling) was unrelated or slightly positively associated with wellbeing [12]. Further research also suggests that specific smartphone activities may have specific associations with health outcomes. David, Roberts, and Christenson (2018) collected objective sensory data in the United States for a one-week period via smartphones, while feelings of wellbeing were self-reported using surveys. They found that studying the overall time spent using a device did not fully explain the relationship between screen time uses and anxiety and depression; rather, specific uses on the smartphone were associated with health outcomes [13]. For instance, time spent using apps for taking photos and videos was associated with higher levels of reported anxiety and depression. On the other hand, time spent using productivity apps was associated with fewer reported relationship conflicts, while book apps were associated with lower levels of anxiety and depression [13]. These findings suggest that smartphone-based screen time usage is varied and potentially has different associations with mental health than that of other types of devices. The cognitive-behavioural model of pathological internet use can further contextualise the literature's findings [14]. It suggests that generalised pathological internet use is to be distinguished from specific pathological internet use; where the latter refers to specific internet use such as online gambling. Additionally, the Uses and Gratifications Theory also highlights that people consume media depending on their own personal needs that can differ due to psychological and/or demographic characteristics [15,16]. Findings from the literature, the cognitive-behavioural model of pathological internet use, and the Uses and Gratification Theory support that smartphone use behaviours differ at an individual level.

A limitation with previous research is the focus on problematic smartphone use and the predominance of adult related literature, with only one-third of the studies addressing youth populations [9,17,18]. Problematic smartphone use is a complex phenomenon con-

sisting of dysfunctional manifestations (i.e., social isolation, diminished self-confidence, depression, and anxiety) [19]. For public health and policy recommendations, studies are needed that evaluate smartphone use with time cut-off points (e.g., hour-based). This will help in the development of smartphone use guidelines for safe everyday use (i.e., do not pose health consequences).

Smartphone guidelines are a delicate matter since digital technology enables social connection, which has been especially important since the coronavirus disease (COVID-19) pandemic began. During this global health crisis, access to digital tools has been invaluable to not only connect socially and maintain mental health while following physical distancing public health orders [20,21], but also to maintain productivity in many sectors [20,22]. While higher volumes of digital device usage and screen time accumulation has become inevitable, it is critical to understand how smartphone screen time is associated with health, particularly in a world where digital engagement has become the primary form of communication [22,23] due to varied motivations such as work, leisure, entertainment, gaming, and social connection [24]. Such findings can not only support the development of prevention policies of harmful behaviours, but also enable the development of ethical digital health interventions [25].

Currently, there are no public health guidelines for smartphone screen time specifically, and there is scarce research on youth's smartphone habits and their relationship with their health. The objective of this study is to investigate the association between smartphone use (internet use, gaming, texting, and total use) and mental health (feelings of anxiety, feelings of depression, and suicide ideation) among urban youth aged 13–21 years to inform future public health guidelines for youth smartphone use.

## 2. Methods

### 2.1. Recruitment and Data Collection

The data for this study were collected as part of the Smart Platform, a citizen science and digital epidemiological initiative for ethical population health surveillance, integrated knowledge translation, and real-time behavioural interventions [26]. The platform combines citizen science, community-based participatory research, and systems science to conduct population health research using digital tools [27]. The Smart Platform is an innovative approach that leverages the market buy-in of smartphones to ethically engage citizens.

A custom-built smartphone app, adapted for the Smart Platform, was used to engage youth participants as citizen scientists to capture behaviour patterns and their relationship with mental and physical health outcomes [26]. Ethics approval for the Smart Platform was obtained from both the University of Regina and the University of Saskatchewan [26]. Following the instructions outlined in Figure 1, participants had the option to download the app using both Android and iPhone smartphones through either the Google Play Store or Apple App Store [26]. Youth (13–21 years) provided all data via their own smartphones, including demographic and subjective data. Previous studies have shown that smartphone apps can be used to collect valid and reliable health data in both rural and urban centres, and within diverse populations; for example, from university students and lower-income families [28–30].

## Download Ethica to become a Citizen Scientist

**ANDROID USERS:** Go to the [Google Play Store](#) and search for "ETHICA"


**IPHONE USERS:** Go to [App Store](#) and search for "ETHICA"

1. Click to download Ethica and sign up by providing your email address
2. At the top of the screen, you will see a plus sign (+), click on it and enter the digits "140" for the study ID.
3. You will see an informed consent page, please read it and provide consent by clicking "Register."

**You are now ready to become a Citizen Scientist!**

**What's next?**

- You will immediately get the **one-time SMART** survey which will take you 20 minutes to complete. You can complete this survey in parts if you wish to do so, but **PLEASE DO NOT CLOSE** the survey. Simply exit Ethica and finish the survey at a later time.



**Figure 1.** Instructions to become a citizen scientist.

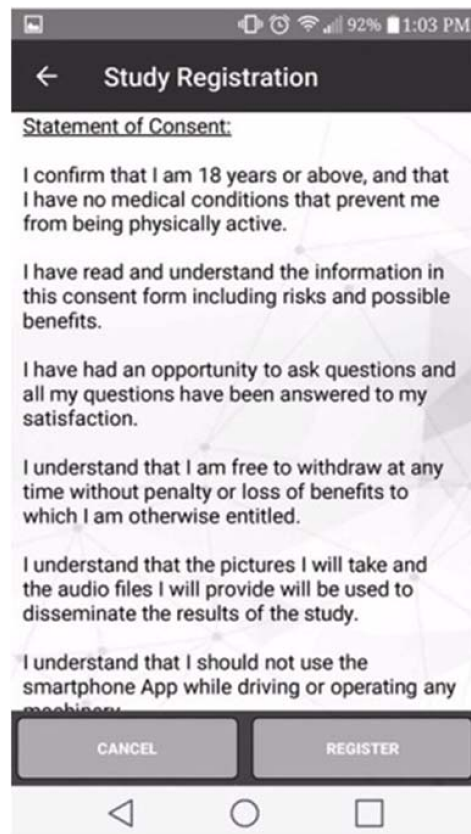
### 2.2. Participants

A total of 808 youth citizen scientists (13–21 years) were recruited through Regina Public and Catholic School engagement sessions held in various high schools throughout Regina, Saskatchewan, Canada in 2018. To recruit citizen scientists, a collaborative relationship was established with school administrators to schedule in-person recruitment sessions. During each session, research team members spent time describing the study, answering questions, and assisting youth to download the study app on their smartphones.

All participants were required to confirm their age, and complete informed consent (Figure 2) via the app on their smartphone. Implied informed consent was provided to the caregivers of each youth (13–16 years) ahead of the recruitment session so that parents had the opportunity to read about the study, ask questions, and contact the research team if they did not want their child to participate in the study. To accomplish this, we collaborated with school administrators who emailed the informed consent forms to each household ahead of a scheduled data collection session. If any parent did not want their child to participate in the study, they could email our team at [smart.study@uregina.ca](mailto:smart.study@uregina.ca) or [smart.study@usask.ca](mailto:smart.study@usask.ca) to notify us.

The smartphone app provided an informed consent section where youth were advised that each participant could refuse to participate in the study or withdraw from the study without any penalty at any time during the data collection cycle (Figure 3). Participants were provided clear instructions on how to withdraw from the study within the app and these instructions were available to them at all times, via the app [26]. Lastly, participants were asked not to change their usual smartphone carrying habits to ensure that objective smartphone phone sensor data were representative of their typical daily living conditions [26].





**Study Registration**

Statement of Consent:

I confirm that I am 18 years or above, and that I have no medical conditions that prevent me from being physically active.

I have read and understand the information in this consent form including risks and possible benefits.

I have had an opportunity to ask questions and all my questions have been answered to my satisfaction.

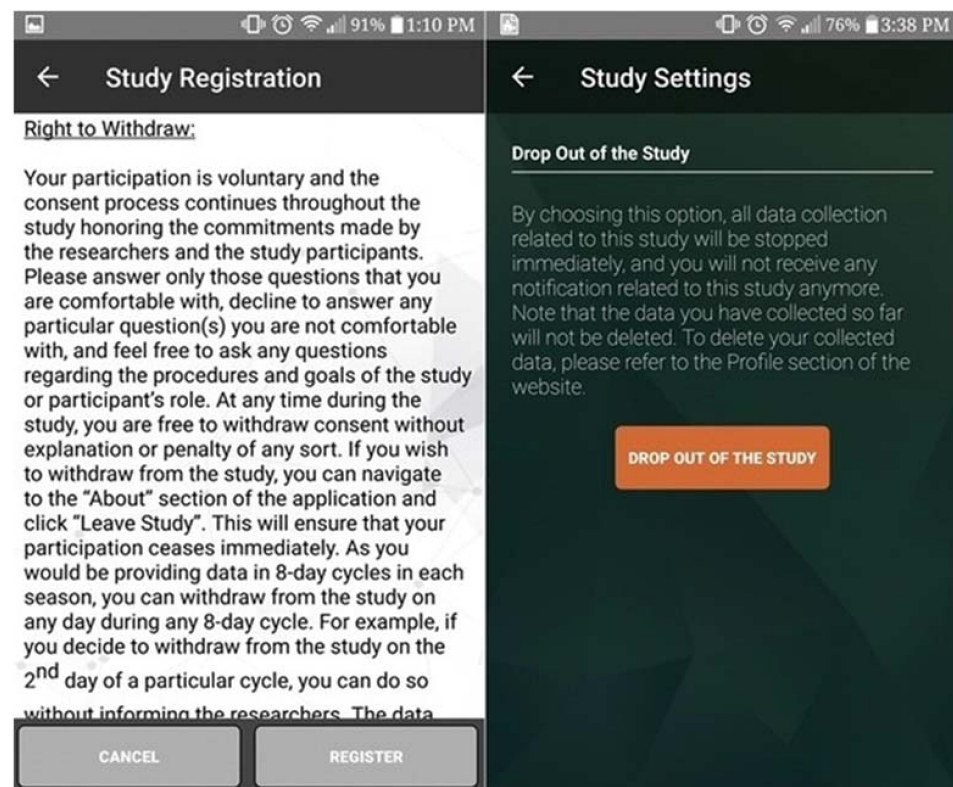
I understand that I am free to withdraw at any time without penalty or loss of benefits to which I am otherwise entitled.

I understand that the pictures I will take and the audio files I will provide will be used to disseminate the results of the study.

I understand that I should not use the smartphone App while driving or operating any machinery.

**CANCEL REGISTER**

Figure 2. Informed consent form.



**Study Registration**

Right to Withdraw:

Your participation is voluntary and the consent process continues throughout the study honoring the commitments made by the researchers and the study participants. Please answer only those questions that you are comfortable with, decline to answer any particular question(s) you are not comfortable with, and feel free to ask any questions regarding the procedures and goals of the study or participant's role. At any time during the study, you are free to withdraw consent without explanation or penalty of any sort. If you wish to withdraw from the study, you can navigate to the "About" section of the application and click "Leave Study". This will ensure that your participation ceases immediately. As you would be providing data in 8-day cycles in each season, you can withdraw from the study on any day during any 8-day cycle. For example, if you decide to withdraw from the study on the 2<sup>nd</sup> day of a particular cycle, you can do so without informing the researchers. The data

**CANCEL REGISTER**

**Study Settings**

Drop Out of the Study

By choosing this option, all data collection related to this study will be stopped immediately, and you will not receive any notification related to this study anymore. Note that the data you have collected so far will not be deleted. To delete your collected data, please refer to the Profile section of the website.

**DROP OUT OF THE STUDY**

Figure 3. Study dropout option in the smartphone app.

### 2.3. Data and Risk Management

To ensure confidentiality, data were encrypted before being stored on the smartphones and streamed to servers when devices established a Wi-Fi connection. Any identifiable artefacts (e.g., photos) were removed or deidentified before data analysis. Permissions built into the Ethica app are restricted so that the app cannot access personally identifiable information that is present on the smartphones (e.g., contact list or network sites visited). MAC address anonymisation was used to protect citizen scientists' data based on a simple hash algorithm. Risks and privacy management options were made clear to citizen scientists while obtaining informed consent. Youth were also advised of the initial data 8 consecutive day collection period, starting on the day they downloaded the app, and that they could request deletion of data even after the data collection. Citizen scientists also had the option in the settings of the app to not only pause data collection, but also to upload data only when they had Wi-Fi access and/or when they were charging their phones. Clear instructions were provided regarding study withdrawal within the app [31].

## 3. Measures

All data were collected during the school year in a single 8-day period. Participants completed the 124-item Smart Youth Survey on their own smartphone device. The survey included several validated self-report surveys that collected sedentary behaviours, screen time behaviours (including smartphone use), demographic characteristics, and health outcomes such as mental health, and subjective wellbeing.

### 3.1. Smartphone Use (Independent Variables)

A modified version of the 9-question Sedentary Behaviour Questionnaire (SBQ) was used to measure screen time use in general [32]. We adapted this survey to capture complex screen time-based behaviours on a variety of digital devices (computer, laptop, tablet, smartphone, etc.) and included options such as internet surfing and social media use [26]. The SBQ was specifically modified to capture comprehensive smartphone use.

Smartphone use in this study is defined as participants self-reporting the amount of time they typically spend engaged in smartphone specific screen time activities. The survey asked youth to report how much time on average they spent on smartphones on a typical weekday and weekend day by categorising the behaviours into the following options: (1) internet surfing (e.g., Facebook, Snapchat, Instagram, YouTube, Reddit, reading news, etc.), (2) playing video games, and (3) texting. This study used these self-reported smartphone usage data to calculate following weekday and weekend day variables: (1) internet use, (2) gaming, (3) texting, and (4) total smartphone screen time. To capture overall smartphone use in a typical week, time spent on a smartphone on a weekday was multiplied by 5 and time spent on a smartphone on a weekend day was multiplied by 2, these products were then summed to create another four variables: (1) weekly internet use, (2) weekly gaming, (3) weekly texting, and (4) weekly smartphone screen time.

There is no public health recommendation for smartphone screen time specifically and the general recommendation for youth recreational screen time usage is less than two hours per day [33]. As such, in this study, a "two hours or more" cut off point was used for weekday and weekend days, and a "14 h or more" cut off point was established for weekly smartphone use—each of these cut-offs will be referred to as "high smartphone use", respectively.

### 3.2. Mental Health Problems (Dependent Variables)

In this study, mental health outcomes included reported measures of symptoms of anxiety, depression, and suicide ideation.

Screening positive for anxiety was measured via the Generalised Anxiety Disorder (GAD-2)'s two questions on anxiety [34]. Youth were asked to respond to the following questions: "How often over the last 2 weeks were you bothered by feeling nervous, anxious, or on edge" and "How often over the last 2 weeks were you bothered by not being able

to stop or control worrying?”. Both these questions had the response options: not at all, several days, more than half the days, or nearly every day. The response options were summed with the lowest (zero) indicating no anxiety symptoms and highest (six) indicating nearly every day experiencing symptoms listed in the GAD-2's questions. As per the guidelines, youth with a GAD-2 score of 3 or higher were classified as screening positive for generalised anxiety disorder [35].

The Smart Youth Survey asked about thoughts about suicide (i.e., suicide ideation) and feelings of depression, consistent with the Youth Risk Behaviour Survey Questionnaire [36]. Youth responded to the following questions: “During the last 12 months, did you ever seriously consider attempting suicide?” and “During the last 12 months, did you ever feel so sad or hopeless almost every day for two weeks or more in a row that you stopped doing some usual activities?”. For both questions, the available response options were “yes” or “no”.

### 3.3. Subjective Mental Health (Dependent Variables)

Finally, for self-rated mental health, youth responded to the question “In general, would you say your mental health is . . . ” with the response options: excellent, very good, good, fair, poor, or do not know. For this analysis, the response “poor” was kept as such and the remaining response options were grouped into one category “Excellent/very good/good/fair” to result in a binary variable for self-rated mental health

### 3.4. Control Variables

While the survey allowed for a variety of options to choose ethnicity, for the purpose of this study, given the Canadian context, categories were adapted to represent the Indigenous (5%), Canadian (39.8%), and other ethnicity (55.2%) populations. Other control variables included in this study were grade with 4 response options (grades 9, 10, 11, or 12), school (1 of 5 participating schools), and gender. Gender was asked via the question “What is your gender?” with the response options: female, male, transgender, other, or prefer to not disclose. For this analysis, since only 5.7% of this study's sample answered with transgender, other, or prefer to not disclose, we grouped these categories into one to result in three gender categories: “female”, “male”, or “transgender/other/did not disclose”.

## 4. Statistical Analyses

Characteristics of the youth were determined by frequencies for binary and categorical variables and means and standard deviations for continuous variables. We used binary regression models to assess for the association between each mental health measure (screening positively for generalised anxiety disorder, suicide ideation, feelings of depression, and self-rated mental health) and smartphone use. To assess for the difference in associations between individual smartphone screen time behaviours versus total smartphone use and the health variables, we had two models for each health variable: one model with the individual smartphone screen time behaviours (internet use, gaming use, and texting use) and another with a sum of the three (total smartphone use). Each model controlled for gender, school, grade, and ethnicity. All analyses were completed using Stata 15.0 [37] with significance set at  $p < 0.05$ .

## 5. Results

Out of 808 youth who were recruited, 437 participants provided relevant data (i.e., more than 25% of the survey was completed by the participant) for this study. From this sample (Table 1), 55.7% identified as female, 38.5% as male, and 5.7% as transgender, other, or preferred not to disclose their gender. The average age was 16 years, and students were recruited from grades 9 (29.7%), 10 (20.4%), 11 (14.5%), and 12 (35.4%).

**Table 1.** Summary characteristics of the sample (N = 436).

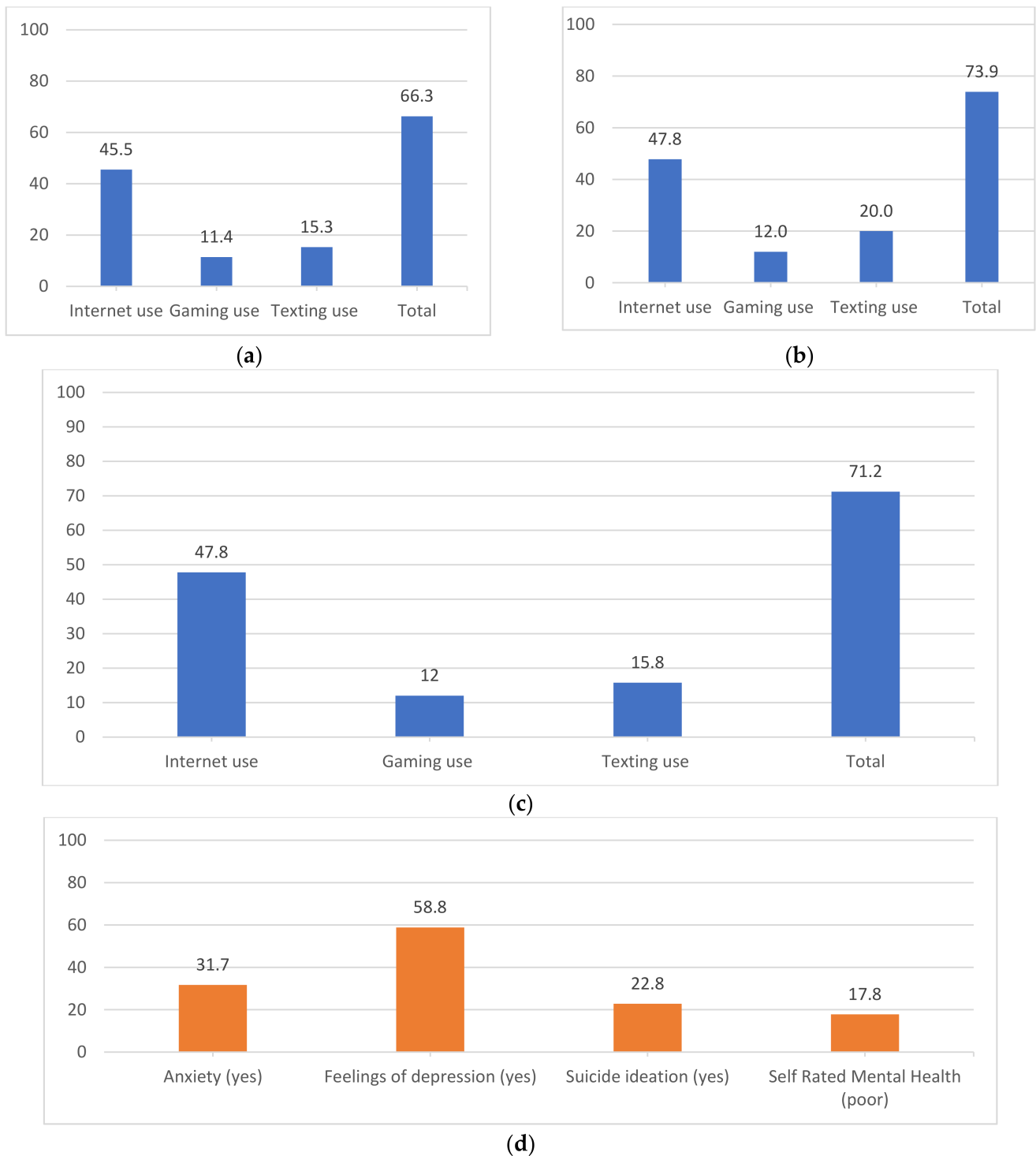
	Proportion (in Percent)	Frequency (n)
Grade		
9	29.7	125
10	20.4	86
11	14.5	61
12	35.4	149
School		
1	25.3	110
2	17.1	74
3	11.5	50
4	18.0	78
5	28.1	122
Ethnicity		
Indigenous	5.0	21
Canadian	39.8	166
Other	55.2	230
Gender		
Female	55.7	233
Male	38.5	161
Transgender/other/did not disclose	5.7	24
	Mean	SD
Age	16.0	1.8

Figure 4 shows the proportion (in percent) of youth reporting high smartphone use (Figure 4a–c), poor mental health, and poor subjective health (Figure 4d). Figure 4a shows that on a typical weekday, 45.5% of participants reported using their smartphone for two hours or more for internet use; 11.4% for gaming; 15.3% for texting; and 66.3% for all behaviours combined. Figure 4b shows that on a typical weekend day, 47.8% of participants reported high smartphone internet use; 12% for gaming; 20% for texting; and 73.9% for all behaviours combined. Figure 4c shows that on a typical week, 47.8% of participants engaged in 14 or more hours of internet smartphone usage; 12.0% gaming on their smartphone; 15.8% texting; and 71.2% on all behaviours combined.

Figure 4d shows the proportion (in percent) of youth reporting poor mental health and poor subjective health. In total, 31.7% of youth reported feeling anxious for several days in a row in recent weeks; 58.8% feeling feelings of depression; and 22.8% considered attempting suicide. For subjective wellbeing, 17.8% of participants rated their mental health as poor.

Table 2 displays results from the regression models that assessed the relationships between high smartphone use with screening positive for anxiety (Models 1–6). Youth who engaged in high total smartphone use over a typical week were 1.83 times (95% C.I. = 1.06, 3.15, results of Model 4) more likely to screen positive for anxiety in the last 2 weeks, relative to their peers. As for single-day smartphone screen time use, Model 6 shows that youth who engaged high smartphone use on a weekday were 1.88 times (95% C.I. = 1.13, 3.13, results of Model 6) more likely to screen positive for anxiety, relative to their counterparts.





**Figure 4.** Proportion (in percent) of youth reporting high smartphone use, poor mental health, and poor subjective mental health. (a) High smartphone use on weekdays. (b) High smartphone use on weekends. (c) High smartphone use during a typical week. (d) Smart youth reporting poor mental health and poor subjective mental health.

**Table 2.** Adjusted relative risk ratios (RRR) and 95% confidence intervals (95% CI) for the association between anxiety <sup>a</sup> (dependent variable) and high smartphone use (independent variables), respectively, among a sample of youth in Canada.

	Weekly Smartphone Use <sup>b</sup>		Weekend Day Smartphone Use <sup>c</sup>		Weekday Smartphone Use <sup>c</sup>	
	RRR	95% CI	RRR	95% CI	RRR	95% CI
	Model 1		Model 2		Model 3	
Internet use	1.27	(0.77–2.10)	1.36	(0.84–2.22)	1.20	(0.73–2.00)
Gaming use	1.62	(0.77–3.40)	1.45	(0.70–3.00)	1.72	(0.81–3.65)
Texting use	1.57	(0.82–3.03)	1.37	(0.77–2.42)	1.50	(0.80–2.96)
	Model 4		Model 5		Model 6	
Total smartphone use	1.83 *	(1.06–3.15)	1.71	(0.97–3.00)	1.88 *	(1.13–3.13)

<sup>a</sup> None (Ref.) versus screened positive for generalised anxiety. <sup>b</sup> Consisted of the sum of 5 weekend and 2 weekday smartphone use. Smartphone use of over 14 h versus less than 14 h (Ref.). <sup>c</sup> Smartphone use over 2 h versus less than the 2 h (Ref.). \*  $p < 0.05$ . All models controlled for grade, ethnicity, school, and gender.

Table 3 shows results from the models that assessed the association between high smartphone use with suicide ideation (Models 7–12). Significant associations were present for suicide ideation when youth engaged in high smartphone gaming use and total smartphone use on weekend days. These youth were 2.90 (95% C.I. = 1.39, 6.03, results of Model 8) and 2.57 times (95% C.I. = 1.28, 5.15, results of Model 11) more likely to report suicidal ideation in the last year, respectively, relative to their peers.

**Table 3.** Adjusted relative risk ratios (RRR) and 95% confidence intervals (95% CI) for the association between suicide ideation <sup>a</sup> (dependent variable) and high smartphone use (independent variables), respectively, among a sample of youth in Canada.

	Weekly Smartphone Use <sup>b</sup>		Weekend Day Smartphone Use <sup>c</sup>		Weekday Smartphone Use <sup>c</sup>	
	RRR	95% CI	RRR	95% CI	RRR	95% CI
	Model 7		Model 8		Model 9	
Internet use	1.16	(0.66–2.03)	0.99	(0.58–1.71)	1.00	(0.58–1.75)
Gaming use	1.64	(0.76–3.54)	2.90 **	(1.39–6.03)	1.79	(0.82–3.88)
Texting use	1.69	(0.85–3.36)	1.25	(0.67–2.30)	1.66	(0.83–3.30)
	Model 10		Model 11		Model 12	
Total smartphone use	1.58	(0.87–2.89)	2.57 **	(1.28–5.15)	1.66	(0.94–2.92)

<sup>a</sup> No (Ref.) versus yes (in the last 12 months). <sup>b</sup> Consisted of the sum of 5 weekend and 2 weekday smartphone use. Smartphone use of over 14 h versus less than 14 h (Ref.). <sup>c</sup> Smartphone use over 2 h versus less than 2 h (Ref.). \*\*  $p < 0.01$ . All models controlled for grade, ethnicity, school, and gender.

Table 4 shows results from the models that assessed the association between high smartphone use with feelings of depression (Models 13–18). Participants who reported high total smartphone use on a typical week were 60.0% (95% C.I. = 0.25, 0.67, Model 16) less likely to report feelings of depression in the last year, than their counterparts. On weekend days, youth with high smartphone gaming use reported lower feelings of depression (RRR = 0.39; 95% C.I. = 0.19, 0.79, Model 14) than their counterparts. Similarly, youth who reported high total smartphone use also reported lower feelings of depression on both weekend days (RRR = 0.27; 95% C.I. = 0.16, 0.47, Model 17) and weekdays (RRR = 0.54; 95% C.I. = 0.34, 0.85, Model 18).

**Table 4.** Adjusted relative risk ratios (RRR) and 95% confidence intervals (95% CI) for the association between feelings of depression <sup>a</sup> (dependent variable) and high smartphone use (independent variables), respectively, among a sample of youth in Canada.

	Weekly Smartphone Use <sup>b</sup>		Weekend Day Smartphone Use <sup>c</sup>		Weekday Smartphone Use <sup>c</sup>	
	RRR	95% CI	RRR	95% CI	RRR	95% CI
	Model 13		Model 14		Model 15	
Internet use	0.85	(0.53–1.35)	0.90	(0.57–1.41)	1.07	(0.67–1.70)
Gaming use	0.53	(0.26–1.07)	0.39 *	(0.19–0.79)	0.51	(0.250–1.06)
Texting use	0.65	(0.35–1.23)	0.69	(0.40–1.19)	0.67	(0.35–1.26)
	Model 16		Model 17		Model 18	
Total smartphone use	0.40 ***	(0.25–0.67)	0.27 ***	(0.16–0.47)	0.54 **	(0.34–0.85)

<sup>a</sup> No (Ref.) versus yes (for 2 weeks in the last year). <sup>b</sup> Consisted of the sum of 5 weekend and 2 weekday smartphone use. Smartphone use of over 14 h versus less than 14 h (Ref.). <sup>c</sup> Smartphone use over 2 h versus less than 2 h (Ref.). \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All models controlled for grade, ethnicity, school, and gender.

Table 5 shows results from the regression models that evaluated the relationships between high smartphone use with self-rated mental health (Models 19–24). Youth who had high total smartphone use on weekend days reported poorer self-rated mental health (RRR = 2.67; 95% C.I. = 1.20, 5.96, results of Model 23).

**Table 5.** Adjusted relative risk ratios (RRR) and 95% confidence intervals (95% CI) for the association between self-rated mental health <sup>a</sup> (dependent variable) and high smartphone use (independent variables), respectively, among a sample of youth in Canada.

	Weekly Smartphone Use <sup>b</sup>		Weekend Day Smartphone Use <sup>c</sup>		Weekday Smartphone Use <sup>c</sup>	
	RRR	95% CI	RRR	95% CI	RRR	95% CI
	Model 19		Model 20		Model 21	
Internet use	1.30	(0.71–2.40)	1.65	(0.91–2.98)	1.15	(0.63–2.10)
Gaming use	1.02	(0.40–2.63)	1.03	(0.40–2.64)	1.13	(0.44–2.92)
Texting use	0.89	(0.39–2.05)	0.66	(0.31–1.41)	0.82	(0.35–1.91)
	Model 22		Model 23		Model 24	
Total smartphone use	1.87	(0.93–3.74)	2.67 *	(1.20–5.96)	1.68	(0.89–3.16)

<sup>a</sup> Excellent/very good/good/fair (Ref.) versus poor. <sup>b</sup> Consisted of the sum of 5 weekend and 2 weekday smartphone use. Smartphone use of over 14 h versus less than 14 h (Ref.). <sup>c</sup> Smartphone use over 2 h versus less than 2 h (Ref.). \*  $p < 0.05$ . All models controlled for grade, ethnicity, school, and gender.

## 6. Discussion

This study investigated the association between youth smartphone use and mental health problems by ethically engaging them via their own smartphones. We found that youth who reported high smartphone use in general were more likely to report poorer mental health. As smartphone usage can vary between weekdays and weekend days as well as by type of activity (social media, texting, etc.) [24], we developed regression models to understand this complexity.

Youth who reported high smartphone use in general reported greater suicide ideation, as well as poorer self-rated mental health on weekend days. On weekdays, youth that had high total smartphone screen time were more likely to screen positively for generalised anxiety.

As for the overall weekly smartphone use models (sum of five weekdays and two weekend days), results showed that youth who reported high smartphone use for texting, gaming, and total smartphone screen time were more likely to report screening positively for anxiety.

We found that high weekend smartphone screen time is associated with a higher number of poor health outcomes relative to weekdays. Specifically, high smartphone use on weekend days was associated with suicide ideation, and poor SRMH, while high smartphone use on weekdays is only associated with screening positive for anxiety. These findings are consistent with research that supports the notion that excessive screen time is associated with anxiety [4,5,38]. However, this study is unique in that these findings were associated with high weekday use of smartphone devices and not all screen time across all devices—a finding that is increasingly pertinent because youth have extensive access to smartphones in the Western world [1].

High smartphone use's association with youth mental health also varied between weekdays and weekend days, a finding that needs further exploration to understand the social and emotional contexts of youth's smartphone use. Current research suggests that passive screen time activities may be associated with poor mental health outcomes, thus, perhaps students are using internet time during the week to complete homework or other learning activities, whereas on the weekend, they may be more engaged in social media or passive activities [13,17]. A report from the United States surveyed children and youth aged 8–18 years of age [39] to find that, on average, youth reported spending over 7 h per day engaged in leisure activities on their smartphone and when learning was involved, this increased to over 9 h per day. Consistent with the existing literature [2,39], our study found that the highest reported smartphone usage was for internet surfing. However, as internet use in our study included a wide range of activities, including social media, future studies should focus on further discerning activity types to better understand their impact on youth mental health.

We also found that high smartphone gaming use was associated with lower risk of feelings of depression. Current evidence on youth gaming is predominantly based on gaming consoles, and not gaming on smartphones. A study in Norway found that gaming use was associated with higher odds of symptoms of depression, although they used a 3 h cut-off compared with our 2 h cut-off and they did not investigate weekday versus weekend day differences [40]. On the other hand, similar to our findings, a meta-analysis (on all screen time) and a recent longitudinal study from the UK (on gaming specifically) reported that more frequent video gaming was associated with fewer depressive symptoms [41,42]. These findings highlight the need for more evidence directed at clarifying the relationship that gaming, and smartphone gaming, has (if any) with feelings of depression among youth both cross-sectionally and prospectively. In line with the cognitive-behavioural model of pathological internet use [14], our findings suggest that smartphone gaming may be a specific behaviour with health outcomes that are different from other smartphone use behaviours.

To develop appropriate policies and interventions, future research should further investigate behaviour-specific (gaming, texting, etc.) associations between high smartphone use and mental health outcomes. Such investigations may also include space-specific investigations (e.g., school versus home use) and the incorporation of other variables associated with poor mental health such as victimisation and overall screen time use.

There are other factors to consider when studying high smartphone use among youth. Dependency on smartphone technology has been found in young age groups, where some youth report feelings of anxiety when their smartphones are not available and they neglect other daily activities to engage in smartphone-based activities [38]. Ease of access to smartphone technology may also be fuelling screen time behaviours, particularly online activities [2]. Smartphone use is associated with poor mental health, particularly depression and anxiety among youth [38]. However, in a study conducted on United States youth aged 13–17 years old, 45% of respondents indicated they did not believe that social media platforms had any impact on their health; while 31% reported a positive impact for reasons mainly associated with the ability to connect with friends/family and 24% reported negative effects for reasons mainly associated with bullying [2]. This indicates the need

for awareness campaigns among youth that address the negative health associations with social media.

While smartphone-based screen time has thus far predominantly been understood as negative, a paradox does exist. Not all smartphone usage necessarily has poor impacts on health. Ecological momentary interventions that are delivered through smartphones have become important mobile health behavioural modification tools [43,44]. An ecological momentary is an intervention or a treatment that targets mental or physical health behaviours and can be deployed through smartphones to individuals in real time [44]. Studies have shown that daily interactions using smartphone technology, to engage with participants, can have positive impacts on wellbeing [43] and physical health [44]. This indicates that future screen time behaviour guidelines should develop smartphone specific recommendations that take into consideration both positive and negative uses of these universal devices

### *Strengths and Limitations*

This study provides significant contributions in providing evidence that high smartphone screen time use has unique associations with mental health outcomes among youth. We also show that it is essential to not just consider individual and total smartphone behaviours, but also the need to consider weekday and weekend day contexts within which these behaviours are exhibited.

As for the limitations, for ease of interpretation, we conducted regression analyses, using a 2 h smartphone use cut-point based on general screen time guidelines. Although innovative and efficient, another potential limitation of this research is that the surveys for this study were deployed entirely through youth owned smartphones, an approach which may have increased the amount of time youth spend on their smartphones. Since the surveys were conducted on their personal smartphones, smartphone use time was self-reported by youth themselves. Future studies should move towards objective measurements to minimise over or under-reporting of usage [24]. Finally, complex movement behaviours such as physical activity and sedentary behaviour should be captured across different seasons, as weather variation can have a significant impact on them [45,46]. Since smartphone use (i.e., screen time) is often used as a proxy for sedentary behaviour, future studies should focus on capturing smartphone use across seasons.

### **7. Conclusions**

This study reports that among youth, high smartphone use was associated with an almost two times higher risk of screening positive for anxiety (specifically, high weekday and high weekly total smartphone use) and an almost three times higher risk of poor self-rated mental health (specifically, high weekend total smartphone use). High smartphone use was also associated with an almost three times higher risk of suicide ideation (specifically, high weekend gaming and high total smartphone use). This study highlights that smartphone use among youth is complex and its association with mental health outcomes varies by not only the type of smartphone use (internet surfing, texting, gaming), but also the type of day (weekday/weekend day). As smartphone market penetration is near universal and since not all smartphone use has negative implications, it is important to develop smartphone-specific screen time guidelines that balance both positive and negative aspects of this device use. Moreover, the deeper understanding of smartphone behaviours and mental health outcomes would not have been possible without the invaluable knowledge provided by youth citizen scientists who participated in this study using their own devices. Both future research and screen time recommendations need to be conducted in partnership with youth to truly co-develop mental health solutions.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki, and approved by the Research Ethics Boards of University of Regina and Saskatchewan through a synchronized review protocol (REB #2017-29).

**Informed Consent Statement:** All participants were required to confirm their age, and complete informed consent via the app on their smartphone. Implied informed consent was provided to the caregivers of each youth (13–16 years) ahead of the recruitment session so that parents had the opportunity to read about the study, ask questions, and contact the research team if they did not want their child to participate in the study. To accomplish this, we collaborated with school administrators who emailed the informed consent forms to each household ahead of a scheduled data collection session. If any parent did not want their child to participate in the study, they could email our team at smart.study@uregina.ca or smart.study@usask.ca to notify us. The smartphone app provided an informed consent section where youth were advised that each participant could refuse to participate in the study or withdraw from the study without any penalty at any time during the data collection cycle. Participants were provided clear instructions on how to withdraw from the study within the app and these instructions were available to them at all times, via the app.

**Data Availability Statement:** The study is part of the Smart Platform, a citizen science and mHealth initiative for ethical surveillance, integrated knowledge translation, and policy and real-time interventions. As this study contains sensitive data such as time-stamped location of citizen scientists, data requests should be sent to the University of Regina's Research Ethics Board at research.ethics@uregina.ca.

**Conflicts of Interest:** The authors declare no conflict of interest.

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