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Quasi-Experimental Evaluation of Text-based Crisis Patterns in Youth following Hurricane Florence in the Carolinas, 2018

Authors: Jennifer D. Runkle^a, PhD, MSPH, Kurt D. Michael^b, PhD, MS, Scott E. Stevens, MS^a, Margaret M. Sugg^c, PhD, MA

^aNorth Carolina Institute for Climate Studies, North Carolina State University, 151 Patton Avenue, Asheville, NC 28801, United States of America, jrunkle@ncsu.edu, 828-257-3030
(Corresponding author)

^bDepartment of Psychology, Appalachian State University, P.O. Box 32066, Boone, North Carolina 28608, United States of America

^cDepartment of Geography and Planning, Appalachian State University, P.O. Box 32066, Boone, North Carolina 28608, United States of America

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1 **ABSTRACT**

2

3 **IMPORTANCE** Crisis text lines have proven to be an effective and low-cost means for
4 delivering texting-based mental health support to youth. Yet there has been limited research
5 examining the use of these services in capturing the psychological impact on youth affected by a
6 weather-related disaster.

7 **OBJECTIVE** This ecologic st adolescents
8 and young adults North and South Carolina, USA, before and after Hurricane Florence (2018).

9 **DESIGN AND MAIN OUTCOMES** A retrospective, interrupted time-series design was used
10 to examine pre- and post-hurricane changes in crisis text volume among youth help seekers in
11 the Carolinas for the following outcomes: (1) text for any reason; (2) stress & anxiety; (3)
12 depression; and (4) suicidal thoughts.

13 **RESULTS** Results showed an immediate and sustained increase in crisis texts for stress/anxiety
14 and suicidal thoughts in the six weeks following Florence. Overall, an immediate 15% increase
15 in crisis texts for anxiety/stress ($SE=.05, p=0.005$) and a 17% increase in suicidal thoughts
16 ($SE=.07, p=0.02$) occurred during the week of the storm. Text volume for anxiety/stress increased
17 17% ($SE=.08, p=0.005$) and 23% for suicidal ideation ($SE=.08, p=0.01$) in the 6-week post-
18 hurricane period. Finally, forecast models revealed observed text volume for all mental health
19 outcomes was higher than expected in the 6 weeks post-Florence.

20 **CONCLUSIONS AND RELEVANCE** A low-cost, crisis texting platform provided 24/7
21 mental health support available to young people in the Carolinas impacted by Hurricane
22 Florence. These findings highlight a new application for text-based crisis support services to
23 address the mental health consequences in youth following a weather-related disaster, as well as

1 the potential for these types of crisis platforms to measure situational awareness in impacted
2 communities.

3

1 **INTRODUCTION**

2 Climatic variability and associated changes in weather patterns are creating new mental
3 health risks and exacerbating existing healthcare disparities (Dodgen et al. 2016, Berry et al.
4 2018). Since the early 1980s, significant changes in the intensity, frequency, and duration of
5 North Atlantic hurricanes have been observed (Wash et al. 2014). A recent NOAA report
6 concludes that both the intensity and associated rainfall of tropical cyclones are likely to increase
7 during the 21st century due to anthropogenic climate change, although it is too soon to
8 conclusively attribute observed changes so far to human activity (Knutson et al. 2019). In the
9 Southeastern US, projected sea-level rise may exacerbate these events (Wash et al. 2014, Carter
10 et al. 2018). The coast of the Southeastern region of the United States is particularly vulnerable
11 to sea-level rise, storm surge, flooding, and hurricanes. In recent years, the Carolinas have been
12 impacted by several billion-dollar events (losses in damage and life), including the record
13 flooding in South Carolina in 2015 (Oct 1-5), Hurricane Matthew in 2016 (Oct 7-9), and
14 Hurricane Florence in 2018 (Sept 13-18) (Carter et al. 2018).

15 Climate change is intensifying the risk, frequency, and severity of natural disasters,
16 especially climate-sensitive disasters relating to hydrological and meteorological hazards posing
17 significant threats to mental health and well-being (Dodgen et al. 2016). Roughly 1 out of 4
18 Americans are under the age of 18 (i.e., ~74 million) and recent estimates show that 14% of
19 individuals in this age group have been exposed to a disaster in their lifetime (Disasters 2010).
20 Dose-response patterns exhibiting increasing exposure and subsequent increases in a wide range
21 of mental health consequences have been identified in adolescents post-hurricane, including
22 serious emotional disturbances (McLaughlin et al. 2009), reactive aggression (Marsee 2008,
23 Scott et al. 2014), depression, anxiety (Costa et al. 2009) and existential anxiety (Weems et al.

1 2016), post-traumatic stress disorder (PTSD)(Goenjian et al. 2001, Kar and Bastia 2006, Kar et
2 al. 2007, Yang et al. 2011), identity distress (Scott et al. 2014), sleep disturbance (Brown et al.
3 2011), and poor academic achievement (Scott et al. 2014). A significant number of empirical
4 studies have documented the persistent effects of disaster-related stressors in young survivors for
5 up to two years and beyond following a hurricane resulting in a disproportionately high
6 prevalence of anxiety, depression, post-traumatic stress, and suicidal ideation (Acierno et al.
7 2007, Felix et al. 2015, Jacobs et al. 205, Lai et al. 2013, McLaughlin et al. 2010, Osofsky et al.
8 2016)

9 While there are multiple drivers in the pathway of psychological disorders following a
10 weather-related disaster, a few potential mechanisms in which climate may be linked to
11 amplified mental health risks include: aggravating root causes of mental illness, traumatic
12 experience, strain on public health-related resources, excess exposure to thermal stress, and loss
13 of individual mental health resources (Berry et al. 2018).

14 Examining the mental health of youth post-disaster may serve as an indicator of recovery
15 efforts and be used to inform targeted interventions in this high-risk group (Abramson et al
16 2010). Crisis text-based counseling services have proven to be an effective and low-cost means
17 of delivering mental health support to individuals struggling with thoughts of suicidality,
18 hopelessness, and psychological pain (Gould et al. 2007, Kalafat et al. 2007). Yet limited research
19 has examined the level of utilization of these mobile crisis counseling services in addressing the
20 psychological impact on youth affected by weather-related disasters.

21 The objective of this retrospective, interrupted time-series study was to evaluate pre- and
22 post-changes in crisis-support seeking patterns among youth impacted in the Carolinas (North
23 Carolina and South Carolina) during and following Hurricane Florence in 2018. Our main

1 hypothesis concerning the impact model of Florence assumed text volume temporarily increased
2 immediately and in the weeks after the storm (i.e., temporary level and slope change). To our
3 knowledge, our study is the first to examine crisis help-seeking behaviors across a large
4 population of youth immediately following a large natural disaster.

5

6 **METHODS**

7 *Storm Impact on Study area*

8 Hurricane Florence (Sept ~13-18th, 2018) made landfall along the coast of North Carolina
9 as a Category 1 storm (Stewart and Berg 2019). Florence was a slow-moving hurricane that
10 generated more than 20inches of rainfall along portions of the coasts of North Carolina (NC) and
11 South Carolina (SC); whereby historic tropical cyclone rainfall records were exceeded in both
12 states (NC: 35.9 inches for Florence (Elizabethtown) compared to 19 inches for Hurricane Floyd
13 (Wilmington) in 1999; SC: 22.6 inches for Florence (Cheraw) compared to 17.5 inches for
14 Tropical Storm Beryl (Lake Jocassee) in 1994) (Steward and Berg 2019). These high-volume
15 rains, in turn, caused substantial low-land and river flooding throughout the Carolinas and
16 surpassed flood stage records captured during Hurricane Matthew in 2016 (USGS 2019). The
17 NOAA National Centers for Environmental Information (NCEI) estimated damages from wind
18 and water during Florence resulted in \$24 billion in losses (e.g., societal disruptions, property
19 damage) and 47 deaths (Stewart and Berg 2019). The damage incurred from Florence in North
20 Carolina exceeds the cost of damages exacted during Hurricanes Matthew (2016) and Floyd
21 (1999) combined (Smith 2019). The region most heavily impacted by Hurricane Florence

1 flooding was predominantly rural inland counties in eastern North and South Carolina with lower

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4 Data on crisis help-seeking patterns were obtained from Crisis Text Line (CTL), a global
5 not-for-profit organization that provides free, 24/7 confidential crisis intervention via a text
6 message platform to youth and young adult populations. Roughly 3 out of 4 CTL texters are
7 below 25 years old, 14% report themselves as Latinx/Hispanic, and 6% report themselves as
8 Native American (Crisis Trends 2018). These data have been used in the context of open data
9 collaborators to understand the relationship between crisis-help seeking in response to
10 temperature extremes (Sugg et al. 2019), the release of the Netflix series *13 Reasons Why*
11 (Thompson et al. 2019, Sugg et al. 2019), and rural versus urban differences in the use of these
12 technology-supported crisis interventions in youth (Thompson et al. 2018). The basic premise is
13 that an individual in crisis can text into the service and be connected with a trained Crisis
14 Counselor. Following each conversation, the counselor assigns data labels to the ‘texter’s issue’
15 or topic areas discussed (e.g., anxiety, stress, suicidal thoughts) based on a list of 35 options (see
16 supplemental Table 1). In some scenarios, a texter can report multiple issues during a
17 conversation. We then parsed crisis tags from CTL conversations to separately code and label
18 the issues discussed for each crisis conversation.

19 Daily CTL conversation counts were aggregated for all NC and SC area codes for the
20 following outcomes before and after the storm: (1) any crisis-text; (2) stress and anxiety; (3)
21 depression; and (4) suicidal ideation. All crisis texts were deidentified to protect privacy and
22 details on the user’s name, date of birth, phone number or contents of the message and were
23 provided for 01 January 2018 to 31 October 2018. This time period was the only data available

1 for sharing at the time of the study team’s request. Data on demographic characteristics were
2 available for a small subset of users (approximately 20% of texters) who agreed to supply these
3 details through a post-conversation survey but were not included in the analysis due to the small
4 sample size.

5 Since CTL’s inception in 2013, crisis counselors have facilitated over 155 million
6 conversations with individuals in crisis. Although CTL crisis services are widely disseminated at
7 the local community level through partnerships with schools, public health officials, and
8 community partners, no strategic efforts are currently made to leverage existing dissemination
9 channels to get the word out about these crisis counseling services in communities impacted by a
10 weather-related disaster. To date, national crisis trends reflect that about 25% of texting volume
11 in NC in SC have been related to anxiety stress (NC ranked 22 and SC 32 out of 50 states), 30 to
12 35% related to depression/sadness (NC ranked 10 and SC 11), and 20 to 25% related to suicide
13 (NC ranked 39 and SC 43).

14 *Emergency Department Visits*

15 Daily emergency department visits for the same period 01 January 2018 to 31 October
16 2018 were obtained from the North Carolina Disease Event Tracking and Epidemiologic
17 Collection Tool (NC DETECT), a statewide surveillance system. ED visits were categorized
18 based on the following *International Classification of Diseases, Tenth Revision, Clinical*
19 *Modification* (ICD-10-CM) diagnosis codes: 1) all mental health disorders (F00 to F99); 2)
20 anxiety (F40 - F48); 3) depression (F32-F33); and 4) suicidal ideation (R45.851) (WHO 2004).

21 All ED visits were associated with the county of residence only for adolescents and
22 young adults (age 15 to 24 years) impacted by the storm in North Carolina. Relying on FEMA

1 Disaster Declaration maps for North Carolina, we assigned each county to one of three Hurricane
2 Florence exposure groups: 1) *directly impacted* counties defined as those who received both
3 individual and public assistance; 2) *indirectly impacted* counties for those who received either
4 individual or public assistance; and 3) *no impact* for counties who received no designation
5 (FEMA 2018).

6 *Pre- and post-hurricane event periods*

7 The study period was restricted to Jan 1 to Oct 31, 2018, based on the available data
8 provided by CTL. We categorized the pre-Florence period as Jan 1, 2018 to September 12, 2018,
9 and the post-Florence period as of September 19, 2018 to October 31, 2018. To evaluate changes
10 in crisis text volume in youth following Florence, we examined the immediate impact on CTL
11 volume during the storm (September 13, 2018, to September 18, 2018) and for three separate
12 post-hurricane scenarios: (1) *acute impact* on CTL volume in the two weeks post-Florence
13 (September 18, 2018, to October 2, 2018); (2) *immediate, continuing impact* on CTL volume ~6
14 weeks after the storm (September 13, 2018, to October 31, 2018); and (3) *delayed, but*
15 *continuing impact* on CTL volume 45 days after the storm (September 19, 2018, to October 31,
16 2018). The time-series included a total of 304 days of crisis-text observations, with 253 days of
17 pre-Florence data and a post-Florence period of 51 days. The specified autoregressive (AR1)
18 model included the effect of Hurricane Florence (i.e., I= intervention) on the dependent variable
19 (i.e., daily crisis texts) during (September 13-18, 2018) and after the storm (September 19, 2018,
20 to October 31, 2018):

21 Equation (1): $(Y_t) = \mu + \omega_1 I_{1,t} + a_t$

1 where Y_t is the dependent variable representing the logarithmic transformation of daily crisis
2 text counts for each of the defined outcomes (i.e., daily texts for youth in North and South
3 Carolina combined), t indexes time, μ is the mean term, $\omega_1 I_1$ is the continual effect of the
4 hurricane (i.e., referred to as the intervention) on the dependent variable during the subsequent
5 51 days, i.e., the percent change after the hurricane event. Log-transformed daily counts of crisis
6 texts were used to stabilize variance and can be interpreted as a percent change in daily text
7 volume post-Florence. The right-hand side of Equation (1) characterizes the AR(1) noise
8 process; whereby a_t is the random error term.

9 *Statistical Analysis*

10 Descriptive statistics were performed to examine the mean daily CTL volume with a 95%
11 confidence interval for each pre- and post-hurricane event period. T-tests were used to examine
12 whether mean daily CTL text volume for each outcome differed by the pre- and post-Florence
13 period ($\alpha=0.05$).

14 We performed an interrupted time series (ITS) analysis to capture the immediate or
15 gradual impact of crisis text patterns in the Carolinas before and after Florence. Autoregressive
16 Integrated Moving Average (ARIMA) models were employed to analyze repeated measures of
17 daily CTL volume data and address autocorrelation between time-series (Gebski et al. 2012,
18 Penford et al. 2013, Wagner et al. 2002). ARIMA models are a flexible and sophisticated class of
19 time-series models that allow for pre- and post-event hypothesis testing. We examined the
20 various fit of autoregressive, moving average, or autoregressive moving average models by
21 stepping through a standardized model fit exercise: (1) model identification, (2) parameter
22 estimation, (3) diagnostic checking for each outcome, (4) pre-/post-event (i.e., intervention)
23 testing, and (5) forecasting (Brocklebank et al. 2018). Model fit was assessed using a number of

1 measures: autocorrelation check for white noise, visual autocorrelation function (ACF), partial
2 autocorrelation function (PACF), and ICAF plots, AIC and SBC criteria, and residual correlation
3 and normality diagnostics were used to select the simplest and best-fit model. The forecasting
4 procedure in PROC ARIMA was used to generate one-step-ahead predictions of the time series
5 using historical data from the fitted model to compare actual versus predicted counts of daily text
6 in the post-Florence period (Brocklebank et al. 2018, SAS Institute Inc. 2014).

7 *Sensitivity Analysis: Changes in ED volume for NC*

8 The storm impacted more individuals ($n=34,710$ applications approved for individual
9 assistance) and counties ($n = 57$ out of 100 counties received major disaster declaration) in North
10 Carolina compared to South Carolina ($n = 5,175$ applications approved for individual assistance,
11 19 out 46 counties received major disaster declaration). In a sensitivity analysis, we examined
12 pre- and post-Florence changes in NC emergency department volume for the following mental
13 health condition categories: 1) any mental health condition, 2) anxiety, 3) depression, or 4)
14 suicidal ideation/thoughts.

15 All ITS analyses were performed using PROC ARIMA in SAS 9.4 statistical software
16 and statistical significance was considered at $p<.05$ (SAS Institute Inc, 2014).

17 **Results**

18 Figure 1 shows daily CTL text volume for each outcome for the duration of the time
19 series (Jan 1 to Oct 31, 2018). CTL volume for any reason peaked 5 and 13 days after the storm,
20 while suicidal thoughts peaked around day 6 and depression peaked on day 13 post-Florence.
21 Table 1 shows the summary statistics on the daily mean for each outcome by the pre-/post-
22 hurricane period. We observed significantly more crisis texts for anxiety and stress, as well as

1 suicidal thoughts in the two weeks after Florence compared to the pre-event period. Daily text
2 volume for anxiety and stress, depression, and suicidal thoughts were significantly higher in the
3 six weeks after the storm compared to the pre-hurricane period.

4 *ARMA Models for Post-Florence Crisis Text*

5 The multiplicative autoregressive ARMA (1,0) model was the best-fit model to examine
6 the change in daily crisis text counts. We observed no seasonal lag in daily crisis text volume
7 within the period examined and therefore did not adjust for seasonality in our models. The
8 impact model results for each outcome for the different hurricane event scenarios are shown in
9 Table 2. We observed that shocks to the daily crisis text rate for each outcome during and
10 immediately after the storm were felt in subsequent days following the storm (Figure 2 a-d).
11 Results showed a statistically significant positive intervention effect for crisis texts related to (1)
12 anxiety & stress and (2) suicidal thoughts for the immediate, continuing impact period, as well as
13 the delayed, continuing impact period post-Florence (Table 2). We observed an immediate 16%
14 (SE=.05, $p=0.005$) and 22% (SE=.07, $p=0.02$) increase in crisis texts for anxiety/stress and
15 suicidal thoughts, respectively, immediately after the storm and a delayed 17% and a 23%
16 increase in texts for anxiety/stress (SE=.08, $p=0.005$) and suicidal ideation (SE=.08, $p=0.01$)
17 after Florence, respectively. Although only marginally significant, a 20% (SE=.10, $p=0.09$)
18 increase in anxiety/stress texts were detected in the two weeks after the storm and an 11%
19 (SE=.06, $p=0.08$) increase in depression-related texts occurred in the post-hurricane period.
20 Results confirm our hypothesis that Hurricane Florence generated an immediate and temporary
21 increase in crisis-text patterns in the six weeks following the storm.

22 *Forecast Modeling of Suicidal Thoughts*

1 Using the AR(1) model, we forecasted daily future crisis texts for youth in the Carolinas
2 post-Florence for each of the intervention periods. The results are one-step-ahead predictions for
3 the first 45 days after the storm. In general, crisis text volume was higher than expected for all
4 four outcomes.

5 *Sensitivity Analysis for NC ED Volume*

6 Daily ED volume increased from the pre- (daily mean of ED visits = 64.5) to post-
7 hurricane period (daily mean for ED visits = 73.0) for directly impacted counties ($t = -7.06, p$
8 $<.0001$) compared to a decrease in mean ED post-Florence (pre-Florence daily mean for ED
9 visits = 91.3 compared to post-daily mean = 83.7; $t = 5.00, p <.001$) for the indirectly impacted
10 communities and no change in ED volume for counties not impacted by the storm (Supplemental
11 Figure 1). ED visits for any mental health condition in youth peaked around 8 days after the
12 storm compared to visits related to depression that peaked around 2 and 5 weeks after the storm.
13 Visits to the ED for suicidal ideation peaked around a week after the storm and then spiked again
14 5 weeks later.

15 Similar to the CTL analysis, we used the AR(1) model to examine the delayed, but the
16 continuing impact of Hurricane Florence on changes in daily ED volume for each of the four
17 mental health conditions in youth. After Florence, we observed a significant 16% increase in ED
18 visits for all mental health conditions (Figure 3a), a 21% higher ED volume for depression
19 (Figure 3b), a 33% increase in visits for suicidal ideation with a peak around 2 weeks and 1
20 month after the storm (Figure 3c), and 23% more ED visits for anxiety among youth (Figure 3d).
21 ED volume for all four conditions abruptly dropped during the week of the storm for impacted
22 communities.

1 *General Crisis Trends*

2 In general, we observed a spike in crisis texts for any reason, depression, anxiety, and
3 suicidal thoughts in January and June of 2018. Some research has demonstrated similar trends
4 concerning a winter peak in mental disorders (e.g., generalized anxiety and mood disorders) and
5 a spring peak in mood disorders or major depression for younger age groups (deGraaf et al.
6 2005). As discussed in a related study, the spike in crisis text volume occurring in June 2018
7 may be attributable to two celebrity suicides and the release of *13 Reasons Why* Season 2 (Sugg
8 et al. 2019). Research has also shown an increase in crisis text patterns in the summer months
9 during anonymously warm conditions in temperate climates (Sugg et al. 2019). Suicide rates
10 generally exhibit a more seasonal trend with higher rates in the spring and summer. Yet, crisis
11 text volume and ED visits for suicidal ideation were much higher post-Florence than patterns
12 observed in the warmer season.

13 **Discussion**

14 This study examined the impact of Hurricane Florence on daily crisis text patterns for
15 adolescents and young adults in the Carolinas. Our results are an original contribution to the
16 literature and are the first to assess near real-time help-seeking behaviors in an impacted
17 population before, during, and after a catastrophic hurricane. We found a significant and
18 sustained increase in crisis-texts for two mental health variables –anxiety/stress and suicidal
19 thoughts– immediately after Hurricane Florence. After controlling for recent shocks in local
20 crisis text patterns (i.e., the AR(1) term), we conclude that the initial and sustained increase in
21 the average daily volume of crisis-texts post-disaster is likely reflective of the mental health
22 experience of impacted individuals in the Carolinas associated with Hurricane Florence and is
23 not likely due to an alternative unobserved factor.

1 These results were confirmed by a sensitivity analysis examining changes in ED volume
2 among those impacted communities in North Carolina. In general, we observed a 16% increase
3 in any mental health-related ED visits for individuals between the ages of 15 and 24 after
4 Florence. ED volume in this group was higher than crisis text volume for all three conditions:
5 anxiety-related ED visits increased 23 % (compared to 17% in CTL volume), depression-related
6 ED visits increased 21% (compared to 11% in CTL volume), and ED visits for suicidal thoughts
7 / ideation increased 33% (compared to 23% in CTL volume).

8 Typically, communities impacted by a natural disaster (e.g., catastrophic hurricane) do
9 not have enough counselors trained to provide citizens with the mental health care services they
10 need after a disaster, particularly during the acute impact period (Wang et al. 2007, Jaycox et al.
11 2010). Our results highlight a notable increase in help-seeking behaviors for trauma-related
12 symptoms (e.g., depression, stress, and anxiety) following Florence. Pina et al. noted that greater
13 helpfulness from extra-familial sources of social support predicted lower levels of self-reported
14 symptoms of post-traumatic stress disorder, anxiety, and depression post-Katrina (Pina et al.
15 2008). It is encouraging that our results suggest adolescents and young adults are willing to seek
16 help during an acutely vulnerable time through a text-based crisis counseling platform (i.e.,
17 Crisis Text Line) to address their distress versus a more traditional and potentially less
18 accessible, clinic-based service.

19 We observed a significant spike in crisis texts and mental health-related ED visits for
20 anxiety post-Florence. Our results are troubling as chronic anxiety is the strongest predictor for
21 more severe, longer-lasting post-traumatic stress conditions among youth following other
22 hurricane events, such as high-intensity storms Andrew (August 1992) and Katrina (August
23 2005) (Jaycox et al. 2010, Le Greca et al. 2013, Weems et al. 2007). Similar to our findings,

1 previous studies have documented an increase in mental health symptoms, including features of
2 PTSD, anxiety, and depression following large hurricane-related flooding events (Lieberman-
3 Cribbin et al. 2017).

4 Early disaster research has linked hurricane exposure with a 31% increase in suicides in
5 the two years following the event among populations directly exposed (Krug et al. 1998).

6 Research has also shown an increased prevalence of post-traumatic stress disorder, major
7 depressive disorder, and anxiety disorders, as important risk factors for suicidal thinking (Krug et
8 al. 1998, Nock et al. 2008, O'Connor and Nock 2008). Temporarily, we found a strong and
9 immediate short-term increase in help-seeking behaviors for suicidal thoughts following
10 Hurricane Florence and then a smaller delayed increase in texts associated with suicidal thoughts
11 within six weeks of the event.

12 Although our data stand in contrast to previous studies that either suggest a drop in
13 suicidality post disaster (Kolves et al. 2013) or as much as a 6 month delay in symptom
14 presentation (PTSD, suicidal ideation) following hurricane Katrina (Kessler et al., 2008), these
15 differences might be attributable to the differential methodological approaches across studies.
16 Our results were obtained spontaneously in real-time without formal recruitment, interviews, or
17 survey procedures, albeit during a shorter time frame (i.e., six weeks versus one-year post-
18 hurricane). Indeed, our results are the first to identify an increase in suicidal thoughts during the
19 acute impact phase and highlight the need to promote low or no-cost text-based mental health
20 crisis resources like Crisis Text Line.

21
22 *Strengths and Limitations.*

1 Our study contributes to the literature in several significant ways. First, unlike the
2 previous research (Wang et al. 2007, Kessler et al. 2008, Galea et al. 2007), which focused on
3 survey responses, psychometric screening scales, and clinical interviews, our study uses an
4 interrupted time-series design. An interrupted time-series design accounts for confounding
5 factors by taking into account pre-Florence trends to better characterize the impact (i.e., level,
6 slope, and changing pattern) and thus is considered a robust tool for evaluating the longitudinal
7 impact of a large scale hurricane (i.e., “natural experiment”) with a specific time of onset (Bernal
8 et al. 2017, Kontopantelis et al. 2015). Additional strengths included the use of daily counts for
9 texting behavior from a nationally available crisis text platform ($n=304$ time points) compared to
10 weekly or monthly counts which significantly increased the power to detect a true difference in
11 crisis behaviors in the post-Florence period. ARIMA models also allow for the adjustment of
12 autocorrelation to account for the delayed influence of crisis texts for a particular outcome earlier
13 in the time-series and the detection of seasonality.

14 Additionally, our study examined a wide range of mental health symptoms of which
15 individuals sought help, including stress, anxiety, depression, and suicidal thoughts; thus
16 providing a broader assessment of mental health concerns and potential crisis events post-
17 hurricane than previous studies which predominantly focused on PTSD and acute stress disorders
18 (e.g., Norris et al. 2002). Our focused analysis of a text-based platform, which provides a more
19 immediate method of capturing the psychological response of young people compared to
20 traditional survey methodologies, may explain why our results differ from previous research.

21 Due to the small sample size of daily texts for each of the outcomes aggregated for North
22 and South Carolina combined, we could not examine changes in daily text rates for individual
23 area codes separately to approximate storm impact (i.e., tease out the difference between highest

1 exposed area and less-exposed areas). Further, because we used aggregated and de-identified
2 crisis text data, we were unable to discern the effect of pre-existing mental health conditions
3 (e.g., previous diagnosis of anxiety or depression) on post-Florence call volume. Research has
4 shown that the mental health consequences of a disaster among survivors with a pre-existing
5 mental health condition (e.g., anxiety, depression) are more severe compared to youth with new
6 and emergent psychological sequelae (Storch et al. 2018). However, state-level data on
7 emergency department visits and mental health care utilization for North Carolina in 2018
8 confirmed trends identified in the CTL text data and showed the magnitude of mental health
9 conditions post-storm for youth in the most impacted areas. Future research is needed to confirm
10 our findings in the context of other hurricanes impacting the Southeast and consider the mental
11 health impacts of hurricanes that produce different effects than Florence (e.g., wind, storm surge,
12 severe flooding).

13 Individual-level risk factors involved in influencing the differential effects of hurricane
14 exposure and experience in youth (i.e., youth adaptation) are low socioeconomic standing,
15 previous experience with a natural disaster, pre-existing mental health conditions (e.g., anxiety,
16 depression, suicidal thoughts), social support, discrimination, and disruption in access to mental
17 health services and medication (Weems et al. 2008, Warheit et al. 1996). We were unable to
18 differentiate if individual-level factors influenced the magnitude of crisis events associated with
19 the increase in adolescent texting behavior, despite previous research showing disparities in
20 mental health outcomes post-disaster among specific sub-populations (Furr et al. 2010). CTL
21 captures volunteer demographic data on texters by sending out a follow-up survey after the call,
22 but only about 4 out of 10 texters complete the survey. Lastly, de-identified crisis conversations
23 did not include information on the magnitude of impact for CTL-users post-storm, and if they or

1 their families were directly impacted through property damage, death, or injury or indirectly
2 exposed as the result of repeated media exposure on the event. Proximity to hurricanes and
3 hurricane-related impacts are important predictors for both immediate and long-lasting mental
4 health impacts (e.g., Furr et al. 2010, Schwartz et al. 2017).

5 *Directions for Future Research.*

6 To date, no published studies were located that used CTL data to examine help-seeking
7 behavior before and after a major hurricane. More research on determining the efficacy of CTL-
8 derived preventive and early intervention crisis service delivery among youth is needed to
9 understand how this low-cost service can be leveraged to reduce the psychological distress of
10 weather-related disasters. Over two decades of research suggests that schools are a de facto
11 mental health system for adolescents (Klontz et al. 2015, Taylor et al. 2012) and school-based
12 interventions have shown a tremendous amount of potential for improving the mental health of
13 this highly vulnerable group by providing enhanced social support (Goldman et al. 2015) and
14 bolstering emotional well-being post-hurricane (Banks et al. 2014). A new avenue of research
15 might involve coupling and mobilizing available services in the schools where these climate
16 events take place and deploying them strategically and immediately in the aftermath (e.g., Banks
17 and Weems 2014, Kirk et al. 2018, Capps et al. 2019). Strategic partnerships involving CTL, the
18 public and mental health community, and schools located in disaster impacted areas may one day
19 involve widely disseminating CTL services as a standard mental health crisis intervention
20 protocol in disaster torn communities.

21 Now with the rapid pace and reach of these text-based media platforms, we have the
22 capacity for situation monitoring to mitigate the impact of disasters in youth. CTL services could
23 be used to target mental health and other social support resources for youth exposed to hurricane-

1 related stress and trauma in both the immediate and prolonged exposure periods. CTL can also
2 be leveraged by the public health and disaster response community as a real-time screening tool
3 to identify impacted areas with persons who are the most in need of supplemental mental health
4 services and monitor the effectiveness of post-disaster mental health interventions.

5 Crisis text line counselors are volunteer-based and undergo a rigorous 200-hour training
6 program. In addition, the current CTL volunteer workforce in the United States is substantial
7 (approximately 5000). Training includes reflective listening, collaborative problem-solving, and
8 crisis management; however, training materials do not specifically address how to respond to
9 severe disruptions occurring in the aftermath of a natural disaster or extreme weather event.
10 Research examining the need for pre-event training among CTL counselors based on the core
11 principles of Psychological First Aid (Brymer et al. 2006) can be used to identify areas in which
12 counselors feel underprepared to address the mental health consequences in youth following a
13 weather-related disaster.

14 *Conclusions.*

15 A lack of mental health resources has been cited as a significant challenge in the
16 aftermath of weather-related disasters. This challenge is particularly problematic for adolescents
17 and young adults, a group that is especially vulnerable to the mental health consequences of
18 disasters and who are typically reluctant to seek help for mental health problems due to
19 misinformation or perceived stigma attached to the receipt of these services. Critical to post-
20 disaster recovery is the ability of a community to address mental health needs, specifically
21 through adequate resources and timely interventions. Technology-based platforms, like Crisis
22 Text Line, provide an opportunity for fast, cost-effective crisis counseling following natural
23 disasters and can be used to lessen the mental health impact in youth post-disaster by increasing

1 the reach while simultaneously reducing the time it takes to access these safety net mental health
2 services.

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