Long-term mental health trajectories across multiple exposures to climate disasters in Australia: a population-based cohort study

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Summary

Background Tracking populations through increasingly frequent climate disasters and understanding what contributes to mental health risks is crucial for adaption and planning for a climate changed world. We aimed to examine mental health trajectories after consecutive climate-related disasters and assess differences in mental health outcomes by temporal proximity to previous disasters and risk profiles.

Methods Using longitudinal population-based Australian data from 2009 to 2019, people who experienced home damage from at least one disaster (flood, bushfire, or cyclone) were included in the exposure population and tracked from pre-disaster to post-disaster years after each exposure. Cumulative mental health effects of each sequential exposure were estimated through various mental health measures using a panel event study design with linear models in comparison to unexposed matched controls, pre-disaster baselines, and across stratified risk groups. The main mental health outcome was measured with the 5-item mental health inventory (MHI-5).

Findings Mental health effects became more severe with successive disasters. MHI-5 scores declined by 1·61 (95% CI –2·69 to –0·52) and 3·37 (–6·45 to –0·29) during the first and repeat disaster exposures, respectively, compared with the year preceding the first disaster. Recovery to a pre-disaster baseline was more delayed with repeat disaster exposures. There were greater declines in mental health when disasters were closer to the previous exposure (1–2 years apart) than further away (3 or more years). Risk factors that shape mental health trajectories either remained consistent across multiple exposures (social support as protective and long-term health conditions as risks) or became more salient during subsequent exposures (lower household income and rural areas more vulnerable to the mental health effects of repeat disasters).

Interpretation Additional disaster exposures were associated with greater declines in mental health and shifts in some risk factors. Multiple disaster exposures must be urgently considered in public health, welfare, and disaster services.

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Introduction

Climate disasters, such as floods, cyclones, and bushfires, present risks to mental health.[1] Previous studies have shown that disaster exposure can be linked with a period of acute distress, and a considerable proportion of exposed populations are likely to develop mental health conditions, such as post-traumatic stress symptoms, anxiety, and depressive symptoms after disasters.[1–4] Disasters also have broader societal impacts relevant to mental health, including environmental change, economic change, and changes in health system functioning.[5] These post-disaster mental health effects are shaped by social determinants at both the individual and community levels.[2,6]

However, disasters do not always occur as singular rare events. The frequency of climate disasters is increasing globally, and this trend is projected to continue to increase with further global warming.[7] There is an urgent need to understand how multiple disasters impact population health and recovery processes.[8] Yet, most research to date has focused on a specified single disaster event.[8,9] Although there is substantial evidence on the mental health risks of a single disaster exposure, literature on the mental health trajectories during and after multiple exposures remains nascent.[8]

Emerging evidence points to the social burden of multiple disaster exposures, with increased risks of mental illness and economic hardship observed in several regions.[10–13] However, existing studies have relied on a total count of disasters to measure past exposures, rather than tracking dynamic changes in affected populations longitudinally over time (including times between exposures) to assess the effect of each additional disaster exposure on mental health and any differences in trajectories between more or less exposed individuals over time.[12–16] These studies have also primarily focused on localised settings, post-disaster periods, subpopulations, or

Research in context

Evidence before this study

We searched Scopus, Web of Science, and PubMed from database inception to July 10, 2024, using the terms: "cascading disaster*" OR "overlapping disaster*" OR "multi* disaster*" OR "compound* disaster*" OR "intersect* disaster*" OR "cumulative disaster*" OR "simultaneous disaster*" OR "concurrent disaster*" OR "consecutive disaster*" OR "repeat* disaster*" OR "recur* disaster*" OR "reoccur* disaster*" OR (multi* hazard*) AND (disaster* OR crisis OR crises OR emergenc*) AND "mental health". Only articles published in English were considered. This search identified that existing studies have relied on a total static count of disasters to measure exposure, and have primarily focused on localised settings, subpopulations, specific extreme weather events, or post-disaster periods that lack representativeness, coverage, and baseline comparison. One study explored the mental health effects of multiple disaster exposures using a non-rolling total count of disasters compared with pre-disaster baseline. However, to our knowledge, the course of mental health across the periods before, during, and after each consecutive disaster has not been studied. There is very little research on the long-term trajectories of mental health across multiple disaster exposures, any differences in trajectories based on risk profiles and the temporal proximity of disaster exposures, and whether mental health might improve or return to a pre-disaster baseline at any timepoint between multiple exposures.

Added value of this study

To our knowledge, this is the first analysis of mental health trajectories to examine changes in mental health in the years that follow first and subsequent disaster exposures. This study contributes knowledge on dynamic changes in mental health over time between disaster exposures, including any recoveries to pre-disaster baselines in the years after each disaster exposure and temporal proximity between disaster exposures, further unpacking differences in these trajectories by risk profiles. Drawing on 10 years of nationally representative data, the study tracks mental health through 5-item mental health inventory scores and the Kessler Psychological Distress Scale in individuals who experienced one or more disasters (flood, wildfire, or cyclone) compared with pre-disaster baselines and unexposed cohorts. Our findings show that there were greater mental health declines with repeat disaster exposure and identify the timing at which certain population groups experienced higher risks to their mental health (eg, younger people, residents in rural areas, and lower socioeconomic households were at higher risk during repeated disaster exposure). We identified statistically significant differences in mental health trajectories across sequential disasters by chronic health conditions, impairment, or disabilities and social support. Individuals who experienced an additional disaster in closer temporal proximity (ie, 1–2 years) after a previous disaster exposure had greater mental health declines than those who did not.

Implications of all the available evidence

Mental health screening, counselling, interventions, and disaster service planning should specifically address the history, timing, and severity of previous disaster exposures in individuals and communities. There is a need for further research to test the extent to which mental health interventions built on the premise of single disaster exposure are effective when applied in different trajectories of multiple disaster exposures.

specific events (eg, Hurricane Katrina) that do not have representativeness, coverage, and baseline comparison.[10,11,17] Furthermore, there is a scarcity of evidence on whether mental health might improve or return to a pre-disaster baseline at any timepoint, and whether mental health trajectories after multiple disaster exposures differ based on the intervals between each disaster and social vulnerabilities.[8]

Attaining a clearer view of long-term trajectories and factors that might modify mental health effects of increased disaster frequency is essential. Climate extremes, like all disasters, have unequal effects that amplify existing social and economic inequities.[6,18] For example, people experiencing poverty are more likely to be displaced by disasters, less likely to receive post-disaster recovery aid, and might have protracted reductions in wellbeing in the aftermath of a disaster.[19] However, there have been inadequate and inconsistent findings to date among the few studies that examined aspects of social vulnerability in relation to mental health after multiple disaster exposures.[8,14] The substantial knowledge gap in understanding long-term mental health trajectories before, during, and after each consecutive disaster exposure, and cumulative effects over time, limits understanding of the temporal impacts of repeat disasters and development of response strategies contextual to disaster experiences and health needs.

Like many regions around the world, a considerable number of Australian communities have experienced multiple disasters over recent decades.[20–22] Australia is at high risk of increasing climate disasters,[23] making the country a particularly relevant context for examining long-term trajectories across multiple exposures. By use of 10 years of nationally representative longitudinal data in Australia, we aimed to examine the mental health effects of multiple climate-related disasters, through tracking individuals from pre-disaster to after each sequential disaster, and to assess differences in mental health effects and recovery trajectories by individual and community risk profiles and temporal proximities between disasters.

Methods

Data

Data were drawn from 11 waves of the Household, Income and Labour Dynamics in Australia (HILDA) Survey from 2009 to 2019. HILDA is a nationally representative (with coverage rules in line with those adopted by the Australian Bureau of Statistics), longitudinal study, with a stratified multistage, clustered sampling design, of more than 11 000 people (with a top-up sample of >5000 people added in 2011) that collects information annually about a wide range of economic, social, and demographic issues and major life events, including climate-related disasters. Most participants (65–83%) are interviewed within 1 month of the anniversary of their previous interview.[24] During the period of the study, 2003 (8·1%) of 24 651 HILDA respondents reported experiencing a climate-related disaster (damaged or destroyed home), with 1685 individuals having experienced one disaster in total, 251 two disasters, and 67 three or more disasters. Individuals with disaster status (484 individuals missing these data) and mental health outcomes (eight individuals missing these data) recorded at baseline (1 year before the first disaster) were included in the analysis, resulting in a sample of 1511 exposed individuals at baseline. Through a matching process, 3880 control participants who had no exposures during the study period were matched at baseline. Ethics approval of the HILDA survey was granted by the University of Melbourne's Human Research Ethics Committee (number 1955879). Oral informed consent was obtained from all participants in the study.

Outcome measures

The main mental health outcome was measured with the 5-item mental health inventory (MHI-5) from the 36-Item Short Form Survey, a standardised and validated measure of self-reported health and wellbeing that has been widely used and researched in health and quality-of-life studies internationally.[25] This instrument has been administered in every wave of the HILDA survey through a self-completion questionnaire, with a low general level of item non-response rates averaging 2·5–2·8%.[24] The MHI-5 assesses the frequency of symptoms of anxiety and mood disturbance over the past 4-week period using five questions with six possible answers and has been used for screening depression and anxiety disorders (appendix p 2).[25] These outcomes are measured on a scale from 0 (poor) to 100 (excellent) and treated as continuous. In sensitivity analyses, we used two alternative outcome measures. We used the Kessler Psychological Distress Scale (K10), a screening scale of non-specific psychological distress in the anxiety–depression spectrum based on ten questions about negative emotional states in the past 4 weeks,[26] with higher scores indicating higher levels of psychological distress, which is available every other year in survey data. Additionally we used a binary indicator of high risks of severe depressive symptoms, defined as MHI-5 ≤52 or ≤76, in line with previous national and international psychiatric literature using different optimisation methods, which is available annually in survey data.

Exposure measures

Exposure to climate-related disasters was measured based on the reporting of respondents on if a weather-related disaster (eg, flood, bushfire, or cyclone) damaged or destroyed their home in the past year. Two levels of exposure were created: the rolling number of disasters that the respondent had experienced (no exposure, first disaster, second disaster, and third disaster) and, for each disaster, the rolling number of years (for the first disaster: 1 year before, disaster year, 1 year after, 2 years after, and 3 years after; for each sequential disaster: disaster year, 1 year after, 2 years after, and 3 years after). The interaction of these two measures was included to capture the trajectories from pre-disaster to post-disaster years after each disaster occurrence. The temporal proximity of disaster events was measured using the years since the previous event, which were categorised into experiencing the previous disaster 1–2 years or 3 or more years apart. Analyses included information from 1-year pre-disaster, the disaster year, and up to 3 years post-disaster for each disaster, limited to three disasters considering the small sample size after the third.

Unexposed population

To compare the populations exposed and unexposed to climate-related disasters, control cohorts who shared similar characteristics with exposed cohorts before the first exposure year were randomly sampled from respondents who never experienced a disaster event between 2009 and 2019. Individuals exposed to a disaster in a particular year were matched with control individuals based on demographic, socioeconomic, housing, health, neighbourhood, and locational characteristics in the year before the disaster. These factors have been identified as key determinants of health risks to climate disasters,[6] including sex, age, education, remoteness (defined by the Australian Bureau of Statistics), area socioeconomic status (based on the Index of Relative Socio-Economic Advantage and Disadvantage developed by the Australian Bureau of Statistics), household structure, equivalised household income, employment status, MHI-5 (deciles), long-term health condition, impairment or disability, housing tenure, dwelling types, area mean housing prices (deciles), states and territories, and climate zones (defined by the National Construction Code). Exposed and control cohorts were dynamically matched using one-to-five nearest neighbour matching with replacements, with the nearest neighbours determined by a weighted function of the covariates for each observation[27] and each control unit included once (appendix p 3).

See Online for appendix

	Unexposed population (n=3880)	Exposed population (n=1511)	Total number of disasters experienced			p value for difference across total disasters
			1 (n=1297)	2 (n=175)	≥3 (n=39)	
Sex						0·66
Female	2037 (52·5%)	784 (51·9%)	667 (51·4%)	95 (54·3%)	22 (56·4%)	
Male	1843 (47·5%)	727 (48·1%)	630 (48·6%)	80 (45·7%)	17 (43·6%)	
Age, years						0·35
<30	1141 (29·4%)	370 (24·5%)	326 (25·1%)	36 (20·6%)	8 (20·5%)	
30–64	2091 (53·9%)	910 (60·2%)	771 (59·4%)	111 (63·4%)	28 (71·8%)	
≥65	648 (16·7%)	231 (15·3%)	200 (15·4%)	28 (16·0%)	3 (7·7%)	
Aboriginal and Torres Strait Islander status						0·03
No	3782 (97·5%)	1461 (96·7%)	1254 (96·7%)	172 (98·3%)	35 (89·7%)	
Yes	97 (2·5%)	50 (3·3%)	43 (3·3%)	3 (1·7%)	4 (10·3%)	
Missing	1 (<0·1%)	0	0	0	0	
Household structure						0·38
Couple without children	1214 (31·3%)	468 (31·0%)	407 (31·4%)	48 (27·4%)	13 (33·3%)	
Couple with children	1765 (45·5%)	612 (40·5%)	531 (40·9%)	68 (38·9%)	13 (33·3%)	
Lone parent	260 (6·7%)	125 (8·3%)	99 (7·6%)	22 (12·6%)	4 (10·3%)	
Lone person	497 (12·8%)	230 (15·2%)	193 (14·9%)	31 (17·7%)	6 (15·4%)	
Other	144 (3·7%)	76 (5·0%)	67 (5·2%)	6 (3·4%)	3 (7·7%)	
Education						0·02
Graduate or postgraduate	846 (21·8%)	311 (20·6%)	272 (21·0%)	26 (14·9%)	13 (33·3%)	
High school or certificate	1866 (48·1%)	756 (50·0%)	636 (49·0%)	99 (56·6%)	21 (53·8%)	
Year 11 or below	1168 (30·1%)	443 (29·3%)	389 (30·0%)	50 (28·6%)	5 (12·8%)	
Employment						0·63
Employed	2475 (63·8%)	959 (63·5%)	832 (64·1%)	103 (58·9%)	24 (61·5%)	
Unemployed	89 (2·3%)	59 (3·9%)	51 (3·9%)	6 (3·4%)	2 (5·1%)	
Not in labour force	1316 (33·9%)	493 (32·6%)	414 (31·9%)	66 (37·7%)	13 (33·3%)	
Household equivalised income, quintile						0·89
Lowest	807 (20·8%)	301 (19·9%)	257 (19·8%)	34 (19·4%)	9 (23·1%)	
2nd	722 (18·6%)	310 (20·5%)	267 (20·6%)	37 (21·1%)	6 (15·4%)	
3rd	737 (19·0%)	287 (19·0%)	239 (18·4%)	40 (22·9%)	8 (20·5%)	
4th	807 (20·8%)	296 (19·6%)	256 (19·7%)	31 (17·7%)	9 (23·1%)	
Highest	807 (20·8%)	317 (21·0%)	278 (21·4%)	33 (18·9%)	7 (17·9%)	
Social support						0·27
Poor	1258 (32·4%)	543 (35·9%)	456 (35·2%)	70 (40·0%)	17 (43·6%)	
Strong	2612 (67·3%)	962 (63·7%)	836 (64·5%)	104 (59·4%)	22 (56·4%)	
Missing	10 (0·3%)	6 (0·4%)	5 (0·4%)	1 (0·6%)	0	
Long-term health condition	931 (24·0%)	490 (32·4%)	403 (31·1%)	70 (40·0%)	15 (38·5%)	0·05
Housing tenure						0·30
Owner	2666 (68·7%)	1052 (69·6%)	892 (68·8%)	128 (73·1%)	33 (84·6%)	
Renter or other	1214 (31·3%)	459 (30·4%)	405 (31·2%)	47 (26·9%)	6 (15·4%)	
Dwelling type						0·12
House	3562 (91·8%)	1369 (90·6%)	1171 (90·3%)	159 (90·9%)	39 (100%)	
Flat, unit, apartment, or other	318 (8·2%)	142 (9·4%)	126 (9·7%)	16 (9·1%)	0	
Remoteness						0·40
Metropolitan area	2580 (66·5%)	786 (52·0%)	682 (52·6%)	86 (49·1%)	17 (43·6%)	
Regional or remote areas	1300 (33·5%)	725 (48·0%)	615 (47·4%)	89 (50·9%)	22 (56·4%)	

(Table 1 continues on next page)

	Unexposed population (n=3880)	Exposed population (n=1511)	Total number of disasters experienced			p value for difference across total disasters
			1 (n=1297)	2 (n=175)	≥3 (n=39)	
(Continued from previous page)						
Area socioeconomic status, quintile						0·32
Lowest	718 (18·5%)	298 (19·7%)	255 (19·7%)	36 (20·6%)	6 (15·4%)	
2nd	738 (19·0%)	348 (23·0%)	292 (22·5%)	50 (28·6%)	6 (15·4%)	
3rd	799 (20·6%)	308 (20·4%)	265 (20·4%)	32 (18·3%)	11 (28·2%)	
4th	795 (20·5%)	277 (18·3%)	239 (18·4%)	28 (16·0%)	11 (28·2%)	
Highest	830 (21·4%)	280 (18·5%)	246 (19·0%)	29 (16·6%)	5 (12·8%)	
Risk of severe depression						
MHI-5 ≤52	551 (14·2%)	243 (16·1%)	202 (15·6%)	34 (19·4%)	7 (17·9%)	0·41
MHI-5 ≤76	1936 (49·9%)	807 (53·4%)	685 (52·8%)	95 (54·3%)	27 (69·2%)	0·13
Mental health score						
MHI-5	73·4 (17·2)	72·0 (18·1)	72·2 (17·9)	70·5 (20·1)	70·1 (15·2)	0·41
K10	15·8 (6·2)	16·1 (6·5)	16·1 (6·5)	16·3 (6·8)	16·9 (5·0)	0·85

Data are n (%) or mean (SD). Data might not be representative of the Indigenous population for every wave, especially in very remote areas. MHI-5=5-item mental health inventory. K10=10-item Kessler Psychological Distress Scale.

Table 1: **Summary statistics of unexposed and exposed populations at 1 year pre-disaster**

Statistical analysis

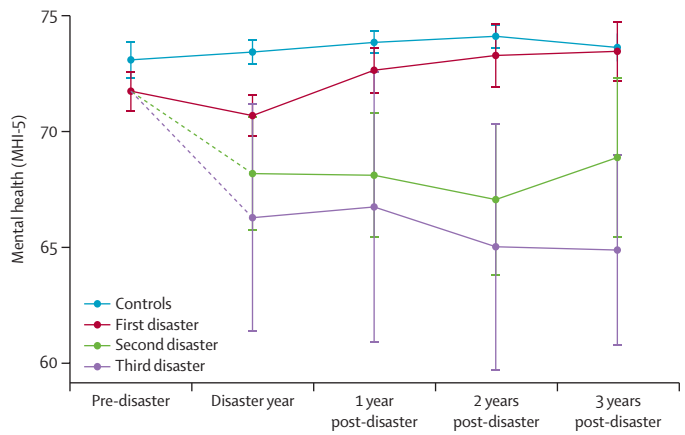
Sample statistics at baseline were presented across groups with different degrees of disaster exposure. Mental health trajectories from pre-exposure to post-exposure compared with unexposed matched controls were depicted using a panel event study design with linear models incorporating fixed effects for local government areas and years. In estimating changes in mental health outcomes between pre-disaster and post-disaster periods, analyses were done using a panel event study design that accounted for dynamic leads and lags, with linear models controlling for social determinant of health inequalities at baseline (largely obtained from in-person interviews) that have been identified in previous studies and reviews as risk factors associated with adverse mental health effects of disasters.,[1,6,8,11,28] These risk factors include sex (female *vs* male), age (<30 years, 30–64 years, or ≥65 years), Aboriginal and Torres Strait Islander (yes *vs* no), education (graduate or postgraduate, high school or certificate, or year 11 or less), remoteness (metropolitan *vs* rural), area socioeconomic status (quintiles of the Index of Relative Socio-Economic Advantage and Disadvantage), household structure (couple without children, couple with children, lone parent, lone person, or other), equivalised household income (quintiles), employment (part-time, full-time, unemployed, or not in the labour force), housing tenure (outright owner, mortgaged owner, or renter), self-reported long-term health condition, impairment, or disability status (yes *vs* no), social support (dichotomised into poor [–3 to 1] or strong [2 to 3] based on a composite score derived from ten questions in the self-completion questionnaire related to accessible social ties;[24] appendix p 4), and other major adverse life events (appendix p 5), along with fixed effects of local government area and year indicators, applying complete case analysis. Self-completion questionnaire respondent sample weights were used to account for non-random response and attrition. Cluster robust SEs were applied to account for correlations of model errors within a given individual or local government area.[29] Sensitivity analyses using alternative modelling strategies, including multilevel mixed effects and fixed effects (within) models, were done (appendix p 6). To investigate varied mental health trajectories of cumulative disasters over time by levels of risk factors, interaction terms between effect modifiers at the first disaster and exposure indicators were included for the stratification analyses. Drawing from climate disaster research,[6,8] identified effect modifiers included individual-level (sex, age, ethnicity, chronic health condition, social capital, housing tenure, education, and household income) and community-level (area socioeconomics and remoteness) social vulnerability factors, and disaster-based risk factors (temporal proximity of disasters). Model specifications are described in the appendix (pp 7–8). Stata/SE version 18.0 was used for data analyses.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Consistent with existing literature,[1] individuals exposed to climate disasters had poorer health than those unexposed



Numbers at levels of exposure across time					
Controls	3880	3414	3254	3140	3062
First disaster	1511	1511	1145	973	803
Second disaster	..	318	214	182	149
Third disaster	..	67	49	40	30

Figure 1: **Trajectories of mental health across groups experiencing different degrees of disaster exposures**
All individuals with exposures to at least one disaster and the general unexposed population were included. Mental health from before the first disaster to after each consecutive disaster and associated 95% CIs are shown. Summary statistics of mental health measures across disasters are provided in the appendix (p 14). MHI-5=5-item mental health inventory.

to disasters (table 1). The likelihood of experiencing multiple disasters was higher among those with long-term health conditions (85 [39·7%] of 214 individuals) or living in regional or remote areas (111 [51·9%] of 214 individuals) at baseline compared with those experiencing a single disaster. Individuals living in more socioeconomically disadvantaged areas pre-disaster were more likely to experience multiple disasters (42 [19·6%] of 214 individuals in the lowest quintile [most disadvantaged] and 56 [26·2%] of 214 individuals in the second lowest quintile, compared with 34 [15·9%] of 214 individuals in the highest [most advantaged] quintile).

We plotted the trajectories of cumulative mental health of exposed individuals from pre-disaster to post-disaster, following each disaster event, and the trajectories of cumulative mental health among the general population unexposed to climate-related disasters (figure 1). Although mental health remained stable with small improvements among the unexposed population, exposure to one disaster led to a decline in mental health during the disaster year, followed by improvements in mental health post-disaster similar to the trend in the unexposed group. However, as the number of disaster exposures increased, mental health trajectories declined further and had longer recovery periods. Exposure to subsequent disasters was associated with larger decreases in mental health during the disaster year compared with the decrease observed in the year of the first disaster, with no clear recovery to baselines observed thereafter.

For the first disaster exposure, there was a statistically significant decrease of 1·61 points in mental health during the disaster year (95% CI –2·69 to –0·52) compared with pre-disaster, and mental health gradually recovered in the first (0·20, 95% CI –1·00 to 1·41), second (0·14, –1·58 to 1·86), and third (–0·11, –2·18 to 1·96) years post-disaster (table 2). When exposed to a second disaster, the decline of 3·37 points (95% CI –6·45 to –0·29) was greater than during the first disaster and intensified with a further decrease at 1 year post-disaster (–4·52, –7·97 to –1·07) rather than a steady recovery as seen after the first disaster exposure. Exposure to a third disaster was associated with non-significant changes in mental health, which might be due to the small number of observations with large variation or the smaller additional effect on mental health from a certain point onwards.

Overall, two distinct patterns of trajectories of mental health outcomes from cumulative disasters by individual-level and community-level risk factors emerged (appendix pp 9–13). First, some groups were more likely to experience mental health declines with repeat exposures to disasters. Female individuals, younger individuals, Indigenous populations, and those in rural areas showed greater declines during subsequent disaster exposures. Similarly, individuals with lower levels of education, households with lower household income, and communities in areas with lower socioeconomic status were more affected by consecutive disasters, although the mental health of higher socioeconomic households and communities showed greater declines in mental health during the initial exposure. Second, some factors consistently moderated the mental health effects of disasters across multiple exposures. Individuals with chronic conditions, impairment, or disabilities, those with poor social support, as well as homeowners with mortgages and renters had more pronounced declines in mental health compared with their counterparts from the first to subsequent disasters.

We recorded the varied consequences of consecutive climate-related disasters on mental health depending on the time elapsed since the previous disaster exposure (figure 2). The closer the current disaster was to the last disaster (1–2 years apart), the greater the decline in mental health compared with pre-disaster.

Results using the K10 and the clinical cutoffs of the MHI-5 as indicators of severe depressive symptoms reveal a consistent pattern, with statistically significant increases in psychological distress (1·01, 95% CI 0·07–1·94) and risks of depression and anxiety disorders (using 52 as cutoff 0·03, 95% CI 0·01–0·05; using 76 as cutoff 0·04, 0·01–0·07) observed during the first disaster year, before signs of recovery emerging afterwards (table 2). Psychological distress and depressive symptoms became more severe and prolonged during the second disaster (using 52 as cutoff 0·07, 0·02–0·12 at the second disaster year and 0·08, 0·02–0·14 at 1 year after the second disaster). Results were similar using multilevel mixed effects and fixed effects (within) models (appendix p 6).

	Mental health	Psychological distress	High risk of depressive symptoms	
	MHI-5	K10	MHI-5 ≤52	MHI-5 ≤76
First disaster				
Disaster year *vs* before disaster one	−1·61 (−2·69 to −0·52)	1·01 (0·07 to 1·94)	0·03 (0·01 to 0·05)	0·04 (0·01 to 0·07)
Year 1 post-disaster one *vs* before disaster one	0·20 (−1·00 to 1·41)	0·10 (−0·52 to 0·72)	0·001 (−0·02 to 0·03)	0·01 (−0·02 to 0·05)
Year 2 post-disaster one *vs* before disaster one	0·14 (−1·58 to 1·86)	0·44 (−0·76 to 1·64)	−0·01 (−0·03 to 0·02)	0·00 (−0·04 to 0·04)
Year 3 post-disaster one *vs* before disaster one	−0·11 (−2·18 to 1·96)	−0·32 (−1·20 to 0·57)	−0·01 (−0·04 to 0·02)	0·01 (−0·05 to 0·06)
Second disaster				
Disaster year *vs* before disaster one	−3·37 (−6·45 to −0·29)	1·48 (0·03 to 2·92)	0·07 (0·02 to 0·12)	0·04 (−0·01 to 0·10)
Year 1 post-disaster two *vs* before disaster one	−4·52 (−7·97 to −1·07)	2·13 (0·23 to 4·04)	0·08 (0·02 to 0·14)	0·08 (−0·01 to 0·16)
Year 2 post-disaster two *vs* before disaster one	−3·59 (−8·01 to 0·84)	1·10 (−0·57 to 2·77)	0·03 (−0·05 to 0·10)	0·09 (0·00 to 0·18)
Year 3 post-disaster two *vs* before disaster one	−4·14 (−8·34 to 0·07)	1·24 (−0·75 to 3·24)	0·04 (−0·04 to 0·11)	0·12 (0·00 to 0·23)
Third disaster				
Disaster year *vs* before disaster one	−1·43 (−7·31 to 4·44)	0·77 (−1·65 to 3·19)	0·06 (−0·06 to 0·17)	0·16 (0·04 to 0·28)
Year 1 post-disaster three *vs* before disaster one	−0·79 (−5·94 to 4·35)	1·73 (−1·19 to 4·65)	0·06 (−0·09 to 0·20)	0·04 (−0·13 to 0·21)
Year 2 post-disaster three *vs* before disaster one	−6·86 (−13·82 to 0·09)	0·94 (−3·03 to 4·90)	0·12 (−0·05 to 0·30)	0·23 (0·09 to 0·37)

Coefficients on the difference between post-disaster timepoints and 1 year before the first disaster and associated 95% CIs are reported. Year 3 post-disaster three *vs* before third disaster was excluded due to the small number of observations. MHI-5=5-item mental health inventory. K10=10-item Kessler Psychological Distress Scale.

Table 2: **Mental health outcomes after cumulative disaster exposures**

Discussion

Drawing on 10 years of longitudinal data that cover pre-disaster and post-disaster trajectories across multiple exposures, this study investigated the long-term mental health effects of successive climate-related disasters, including floods, bushfires, and cyclones, in Australia. The study examined the mental health trajectories of individuals each year after exposure to one, two, or three disasters compared with pre-disaster baselines and compared with those of the general unexposed population. We also showed how mental health effects and recoveries from cumulative exposures varied based on risk factors.

Our results indicate that mental health worsened with multiple disaster exposures, with MHI-5 scores declining by 1·61 points after the first exposure and by 3·37–4·52 points after the second exposure. The risk of depressive symptoms increased by 3–4% after the first disaster exposure and by 7–8% after the second exposure. The effect sizes observed during the first and second exposures were considered small (less than 4 points) and moderate (4–10 points), respectively, and were of clinical relevance,[25,30,31] similar to other major life hardships (eg, 3·5 points for job insecurity, 4·6 points for energy poverty, and 6·2 points for marital separation). Although individual-level score changes were relatively small, the consistent declines from the first to repeat disasters suggest that, on a population level, these changes could have important implications, especially with the projected increase in climate disasters.

Although there was evidence of recovery to pre-disaster levels of mental health after the first disaster, repeat disasters showed delayed or impeded recovery. These differences in mental health recoveries suggest that the experience of repeat disasters might wear down an individual's resources and ability to respond and recover. Our findings provide crucial insights into the support systems and strategies needed across different exposure points and underscore the need for health, housing, and social support interventions that recognise and incorporate the potential for cumulative stressors and trauma resulting from multiple disasters. Previous reviews have shown that the prevalence of depression and anxiety can remain elevated for years after a single disaster among severely affected populations,[2] and there is growing evidence that exposure to a higher total number

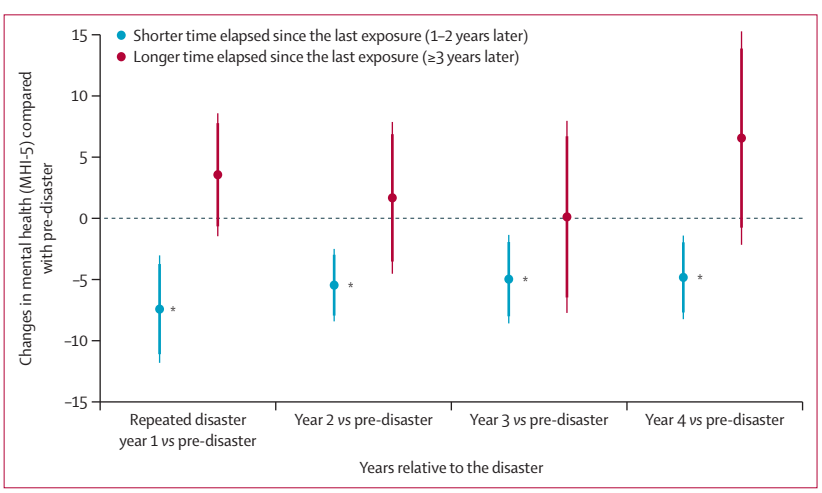


Figure 2: **Variation in mental health consequences of repeat disaster exposure (after second disaster and beyond) according to temporal proximity to the previous disaster**

Individuals exposed to at least two disasters were included. Coefficients on the difference in mental health between 1 year before the first disaster and after each repeat disaster (ie, the second or third disaster event) and associated 90% CIs and 95% CIs are shown, represented by thick and thin lines, respectively. The test result on the difference in temporary proximity was p=0·10. MHI-5=5-item mental health inventory. *Indicates significance at 1%

of disasters is associated with greater risks to mental health,[8,11,13,14] which aligns with the findings of this study. Building on these previous studies that used disaster exposure as a count measure,[12,13] the present analysis contributes knowledge on dynamic changes in mental health over time between disaster exposures, including any recoveries to pre-disaster baselines in the years after each disaster exposure and temporal proximity between disaster exposures, further unpacking differences in these trajectories by risk profiles.

Previous studies on post-disaster mental health trajectories have found differences by subpopulations,[1–3] yet most of this literature has focused on trajectories after one disaster. This study identifies how different risk factors shape mental health trajectories after multiple disaster exposures, revealing two distinct patterns. First, certain risk factors modified mental health trajectories consistently across multiple exposures. Chronic health conditions, impairment or disabilities, poor social support, and living in rental housing were associated with worse mental health effects across all instances of exposure, irrespective of whether this was the first or subsequent disaster. Second, the role of certain risk factors became more pronounced with repeat exposure. Female individuals, younger people, lower socioeconomic households, and residents in rural areas were particularly vulnerable to mental health effects of repeat disasters.

The variation in mental health trajectories by risk factors shows the importance of considering changes in risk and resilience among certain groups with cumulative disasters. The mental health of young to middle-aged populations was more affected by repeat disasters, which is consistent with findings from previous studies and reviews that showed older age was protective against developing post-traumatic stress symptoms, anxiety, and depression more than 24 months after a disaster, and that younger and middle-aged adults showed greater stress responses after disasters. This finding might reflect fewer social and financial burdens and stronger coping and emotional regulation abilities of older adults, which protect them from long-term psychophysical effects.[2,32] Renters experienced delayed recovery, highlighting the acute residential instability and disrupted social connections that can affect renters.[1] There were more considerable declines after repeat exposure to disaster for those in rural areas and with lower socioeconomic status, contributing to discussions of urban–rural and socioeconomic differences in disaster vulnerability[6,33] and underscoring the need for nuanced understanding to address mental health risks from multiple climate disasters. The effects observed in rural areas after consecutive events might be attributed to reduced access to services after disasters,[34] which might be further exacerbated by occurrence of multiple disasters. The potential for targeting interventions to ensure reach to specific population groups, such as younger adults, those with pre-existing health conditions, and those experiencing socioeconomic disadvantage, could be crucial in the context of repeated climate disasters.

There are a range of interventions that can provide mental health and psychosocial support after disasters, including brief and low-intensity (eg, psychoeducation, social support programmes, and skills training) and high-intensity psychotherapeutic interventions.[35,36] The present findings contribute to the understanding of potentially effective measures in multi-disaster settings, particularly in relation to focusing on social connections that have been shown to protect mental health and intentionally including people with long-term health conditions, impairment, or disabilities or in rental housing.[3,37] Our study expands this knowledge by showing that social support and connections consistently predict smaller mental health effects from repeat exposure whereas chronic health conditions, impairment, or disabilities persist as risk factors linked to more severe impacts of multiple disaster exposures. Future work in this area would be beneficial to examine how to effectively link community-level interventions that target social connection and health-inclusive disaster risk reduction to promote integrated approaches to addressing disaster-related mental health.

This study shows possible intervention points for communities experiencing climate disasters. Mental health effects intensified after the first disaster exposure, with trajectories deteriorating from pre-disaster baseline during the second exposure and the degree of deterioration varying based on risk factors. These results show the importance of understanding long-term, nuanced risks to mental health from multiple disaster exposures, particularly the increased vulnerability in cases where individuals have experienced repeat exposure in close temporal proximity. The increased risk of mental health decline among individuals recently exposed to disasters underscores that communities experiencing disasters in quick succession should be targeted for further support. A key gap in practice is that most disaster recovery programmes are based on the premise of a single disaster. One-off or event-based recovery programmes that react to disasters as single events are likely to be insufficient in cases where multiple disasters have occurred or are occurring.[38] Previous studies have recommended extended mental health support to be provided by governments for 5 years after a single disaster,[39] and the present findings support this recommendation, highlighting that this time period should potentially be increased in settings where two or more disasters have consecutively occurred. Our study additionally highlights that mental health care should be part of ongoing discussions to update health-care systems to improve provision of services to address the health risks of disasters,[28] and population-oriented disaster risk reduction strategies require investment to effectively mitigate these risks.

Our study has limitations. First, data on the type of disaster experienced or severity of the experience were not available, and the disaster exposure measure was based on housing damage from a disaster reported by participants. Other forms of disaster exposure (eg, fear for one's life, close vicinity, financial losses, injuries, and fatalities) are unrepresented in the current findings. There are ongoing discussions on how to improve disaster exposure measures across data sources.[40] Future studies could consider linking participant data to external sources on disaster exposure to improve exposure specificity and veracity. Second, as with many other longitudinal studies, the exact timing of events was not available, limiting our ability to determine the precise temporal proximity between disasters and between the timing of disasters and mental health measurements. Nevertheless, using categorical measures for temporal proximity preserved the broad ordering of time elapsed. Third, the study tracked general declines and recoveries in self-reported mental health with MHI-5 and K10. Although these instruments have been validated as a measure of depression using clinical interviews and, more broadly, as a screening tool for generalised anxiety disorder and post-traumatic stress disorder in the general population,[25] further study into trajectories of specific conditions using objective measures would be beneficial to inform more specific mental health interventions and reduce measurement bias. Fourth, disaster exposure was measured from the start of the study period and individuals might have experienced exposure earlier in their lives. Considering lifetime disaster exposures would be relevant for future studies, for example, through linking with administrative data or directly asking for self-reports in questionnaires, as part of continued efforts to improve systematic and consistent exposure measurements of disasters.[40] Fifth, the modest sample size for three disasters (or more) introduces uncertainty and limits our ability to draw strong inferences about effect. When more data after repeat disaster exposure become available, extended longitudinal analyses would provide more power to test higher numbers of exposures. Lastly, although data were limited to pre-COVID-19 to minimise the impact of system shock, the pandemic and related events as additional stressors might amplify mental health effects of disasters.

In conclusion, by examining mental health trajectories after first and subsequent disaster exposures and exploring variations in recovery trajectories, this study illustrates the long-term mental health effects in Australian populations exposed to multiple climate disasters. Our findings suggest that the history of past disaster exposures (eg, first or cumulative, recent or further in the past) are relevant to consider in planning for mental health services and interventions in a climate-changed world, as they might map onto different levels of need for support services. Further research is needed to examine possible variations depending on disaster types and severity of exposures at different disaster timepoints and to understand the implications for how these findings might fit into disaster preparedness, response, and recovery efforts, particularly when preparedness, response, and recovery might be happening at the same time among multi-exposed populations.

Contributors

All authors contributed to the study conceptualisation, design, investigation, interpretation, and presentation of the results. AL led the analyses with input from CL. All authors had access to and verified the data. All authors drafted and revised the manuscript and were responsible for the decision to submit the manuscript for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Data supporting this study are available from the Department of Social Services Longitudinal Studies Dataverse. Requests to access the data should be directed to the Australian Government Department of Social Services at https://dataverse.ada.edu.au/dataverse/hilda.

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