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Supplementary data

Spatiotemporal heterogeneity in the association between extreme temperatures and childhood mental disorders: a global analysis from 1990 to 2021

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1. Supplementary tables

Table S1. Sensitivity analyses using alternative temperature thresholds for associations for extreme temperatures with childhood mental disorders.

Outcome	Exposure	Sex	Est (95% CI)	p value
Mortality	Excess Heat	Male	4.10×10^{-6} (2.63×10^{-6}–5.58×10^{-6})	< 0.001***
	Excess Cold		-4.16×10^{-7} (-1.31×10^{-6}–4.82×10^{-7})	0.364
	Heatwaves		5.48×10^{-5} (3.81×10^{-5}–7.16×10^{-5})	< 0.001***
	Coldwaves		1.28×10^{-5} (-2.92×10^{-6}–2.85×10^{-5})	0.11
	Excess Heat	Female	4.10×10^{-5} (2.56×10^{-5}–5.64×10^{-5})	< 0.001***
	Excess Cold		2.58×10^{-5} (1.65×10^{-5}–3.51×10^{-5})	< 0.001***
	Heatwaves		2.94×10^{-4} (1.19×10^{-4}–4.68×10^{-4})	< 0.001***
	Coldwaves		2.38×10^{-4} (7.50×10^{-5}–4.02×10^{-4})	0.004**
	Excess Heat	Total	2.23×10^{-5} (1.45×10^{-5}–3.01×10^{-5})	< 0.001***
	Excess Cold		1.24×10^{-5} (7.72×10^{-6}–1.71×10^{-5})	< 0.001***
	Heatwaves		1.74×10^{-4} (8.59×10^{-5}–2.62×10^{-4})	< 0.001***
	Coldwaves		1.25×10^{-4} (4.20×10^{-5}–2.07×10^{-4})	0.003**
Incidence	Excess Heat	Male	9.04 (7.90–10.18)	< 0.001***
	Excess Cold		1.74 (1.04–2.45)	< 0.001***
	Heatwaves		28.03 (14.86–41.21)	< 0.001***
	Coldwaves		18.80 (6.45–31.15)	0.003**
	Excess Heat	Female	16.69 (14.39–19.00)	< 0.001***
	Excess Cold		4.38 (2.96–5.81)	< 0.001***
	Heatwaves		63.18 (36.65–89.71)	< 0.001***
	Coldwaves		26.83 (1.94–51.73)	0.035*
	Excess Heat	Total	12.82 (11.16–14.47)	< 0.001***
	Excess Cold		3.04 (2.02–4.07)	< 0.001***
	Heatwaves		45.20 (26.07–64.34)	< 0.001***
	Coldwaves		22.49 (4.54–40.44)	0.014*

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Table S1. *Cont.*

Outcome	Exposure	Sex	Est (95% CI)	p value
Prevalence	Excess Heat	Male	24.27 (20.81–27.73)	< 0.001***
	Excess Cold		6.31 (4.18–8.45)	< 0.001***
	Heatwaves		190.93 (151.32–230.54)	< 0.001***
	Coldwaves		161.78 (124.62–198.94)	< 0.001***
	Excess Heat	Female	17.77 (14.62–20.92)	< 0.001***
	Excess Cold		0.28 (−1.66–2.22)	0.777
	Heatwaves		87.07 (51.03–123.12)	< 0.001***
	Coldwaves		60.69 (26.89–94.48)	< 0.001***
	Excess Heat	Total	21.02 (17.85–24.18)	< 0.001***
	Excess Cold		3.34 (1.38–5.29)	< 0.001***
	Heatwaves		138.68 (102.38–174.98)	< 0.001***
	Coldwaves		111.01 (76.96–145.06)	< 0.001***

Extreme temperature exposure was redefined using the 5th and 95th percentile thresholds. Estimates represent associations between extreme temperature exposure and childhood mental disorder incidence, prevalence, and mortality rates, based on linear mixed−effects models. Rates are expressed per 100,000 population. CI = confidence interval. Asterisks indicate statistical significance (*p < 0.05, **p < 0.01, ***p < 0.001).

Table S2. Sensitivity analyses using alternative temperature thresholds for associations between childhood extreme temperatures and DALYs of mental disorders.

Outcome	Exposure	Sex	Est (95% CI)	p value
DALYs	Excess Heat	Male	597.97 (300.13–895.81)	< 0.001***
	Excess Cold		63.54 (−116.49–243.58)	0.489
	Heatwaves		7253.53 (3879.64–10627.41)	< 0.001***
	Coldwaves		7680.20 (4520.03–10840.38)	< 0.001***
	Excess Heat	Female	485.91 (220.63–751.18)	< 0.001***
	Excess Cold		74.38 (−85.92–234.67)	0.363
	Heatwaves		5160.80 (2153.22–8168.38)	< 0.001***
	Coldwaves		5330.62 (2512.77–8148.47)	< 0.001***
	Excess Heat	Total	1083.00 (522.73–1643.28)	< 0.001***
	Excess Cold		137.22 (−201.38–475.82)	0.427
	Heatwaves		12408.32 (6058.32–18758.33)	< 0.001***
	Coldwaves		13010.10 (7061.46–18958.74)	< 0.001***

Extreme temperature exposure was redefined using the 5th and 95th percentiles. Estimates represent associations between extreme temperature exposure and the absolute number of disability−adjusted life years (DALYs) for childhood mental disorders, based on linear mixed−effects models. Values are expressed as DALYs. CI = confidence interval. Asterisks indicate statistical significance (*p < 0.05, **p < 0.01, ***p < 0.001).

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Table S3. Sensitivity analysis excluding geographically large countries for associations for extreme temperature with childhood mental disorders.

Outcome	Exposure	Sex	Est (95% CI)	p value
Mortality	Excess Heat	Male	2.30×10^{-6} (1.66×10^{-6}–2.94×10^{-6})	< 0.001***
	Excess Cold		-0.67×10^{-6} (-1.08×10^{-6}–0.26×10^{-6})	0.001**
	Heatwaves		12.07×10^{-6} (2.80×10^{-6}–21.34×10^{-6})	0.011*
	Coldwaves		2.91×10^{-6} (-5.79×10^{-6}–11.60×10^{-6})	0.512
	Excess Heat	Female	20.89×10^{-6} (14.27×10^{-6}–27.51×10^{-6})	< 0.001***
	Excess Cold		8.89×10^{-6} (4.69×10^{-6}–13.09×10^{-6})	< 0.001***
	Heatwaves		90.42×10^{-6} (-5.33×10^{-6}–186.16×10^{-6})	0.064
	Coldwaves		43.03×10^{-6} (-46.77×10^{-6}–132.82×10^{-6})	0.348
	Excess Heat	Total	11.48×10^{-6} (8.13×10^{-6}–14.83×10^{-6})	< 0.001***
	Excess Cold		4.03×10^{-6} (1.90×10^{-6}–6.16×10^{-6})	< 0.001***
	Heatwaves		51.81×10^{-6} (3.30×10^{-6}–100.33×10^{-6})	0.036*
	Coldwaves		23.65×10^{-6} (-21.85×10^{-6}–69.15×10^{-6})	0.308
Incidence	Excess Heat	Male	3.16 (2.70–3.63)	< 0.001***
	Excess Cold		1.02 (0.72–1.32)	< 0.001***
	Heatwaves		12.75 (5.94 –19.56)	< 0.001***
	Coldwaves		5.49 (−0.90–11.89)	0.092
	Excess Heat	Female	5.97 (5.03–6.92)	< 0.001***
	Excess Cold		2.01 (1.40–2.62)	< 0.001***
	Heatwaves		29.51 (15.72–43.29)	< 0.001***
	Coldwaves		13.85 (0.90–26.79)	0.036*
	Excess Heat	Total	4.56 (3.88–5.24)	< 0.001***
	Excess Cold		1.51 (1.07–1.95)	< 0.001***
	Heatwaves		20.95 (11.04–30.86)	< 0.001***
	Coldwaves		9.52 (0.22–18.83)	0.045*
Prevalence	Excess Heat	Male	6.51 (5.11–7.91)	< 0.001***
	Excess Cold		2.51 (1.61–3.40)	< 0.001***
	Heatwaves		68.39 (48.18–88.61)	< 0.001***
	Coldwaves		62.06 (43.10–81.01)	< 0.001***
	Excess Heat	Female	5.74 (4.45–7.04)	< 0.001***
	Excess Cold		−0.11 (−0.95–0.72)	0.790
	Heatwaves		33.43 (14.63–52.23)	< 0.001***
	Coldwaves		21.48 (3.85–39.12)	0.017*
	Excess Heat	Total	6.10 (4.81–7.39)	< 0.001***
	Excess Cold		1.20 (0.37–2.03)	0.005**
	Heatwaves		50.39 (31.66–69.12)	< 0.001***
	Coldwaves		41.32 (23.75–58.88)	< 0.001***

Sensitivity analyses were conducted by excluding the seven geographically largest countries (Russia, Canada, China, the United States, Brazil, Australia, and India). Estimates represent associations between extreme temperature exposure and childhood mental disorder incidence, prevalence, and mortality rates, based on linear mixed−effects models. Rates are expressed per 100,000 population. CI = confidence interval. Asterisks indicate statistical significance (*p < 0.05, **p < 0.01, ***p < 0.001).

Table S4. Sensitivity analysis excluding geographically large countries for associations between childhood extreme temperatures and DALYs of mental disorders.

Outcome	Exposure	Sex	Est (95% CI)	p value
DALYs	Excess Heat	Male	150.91 (93.41–208.40)	< 0.001***
	Excess Cold	Male	82.84 (46.27–119.42)	< 0.001***
	Heatwaves	Male	1043.31 (206.97–1879.65)	0.015*
	Coldwaves	Male	1074.27 (289.94–1858.60)	0.007**
	Excess Heat	Female	135.15 (77.43–192.87)	< 0.001***
	Excess Cold	Female	71.24 (34.51–107.96)	< 0.001***
	Heatwaves	Female	758.33 (−80.93–1597.59)	0.077
	Coldwaves	Female	773.23 (−13.86–1560.31)	0.054
	Excess Heat	Total	286.08 (171.26–400.89)	< 0.001***
	Excess Cold	Total	154.03 (80.98–227.08)	< 0.001***
	Heatwaves	Total	1800.59 (130.47–3470.71)	0.035*
	Coldwaves	Total	1846.39 (280.10–3412.67)	0.021*

Sensitivity analyses were conducted by excluding the seven geographically largest countries (Russia, Canada, China, the United States, Brazil, Australia, and India). Estimates represent associations between extreme temperature exposure and the absolute number of disability−adjusted life years (DALYs) for childhood mental disorders, based on linear mixed−effects models. Values are expressed as DALYs. CI = confidence interval. Asterisks indicate statistical significance (*p < 0.05, **p < 0.01, ***p < 0.001).

Table S5. Relative uncertainty of GBD estimates across SDI groups.

Outcome	SDI group	Country−years (n)	Median (Q1–Q3), %
Incidence	Low	1893	39 (36–41)
	Low−middle	1696	36 (33–40)
	Middle	1171	36 (34–40)
	High−middle	1129	35 (33–39)
	High	639	37 (33–40)
Prevalence	Low	1893	31 (30–33)
	Low−middle	1696	32 (30–33)
	Middle	1171	31 (29–33)
	High−middle	1129	30 (29–33)
	High	639	31 (27–33)

Relative uncertainty interval (UI) width was calculated as (upper bound – lower bound)/point estimate × 100%. SDI categories were assigned annually from 1990 to 2021. Values are presented as medians and interquartile ranges across country−year observations.

2. Supplementary figures

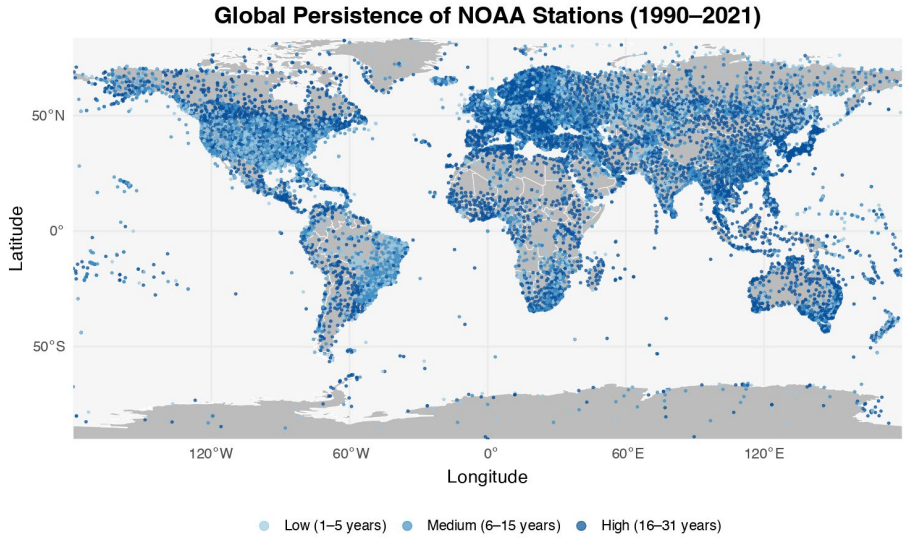


Figure S1. Global persistence of NOAA meteorological stations in 1990 and 2021. Colors indicate the frequency with which each station appeared across the 1990−2021 period, categorized as Low (1−5 years), Medium (6−15 years), and High (16−31 years).

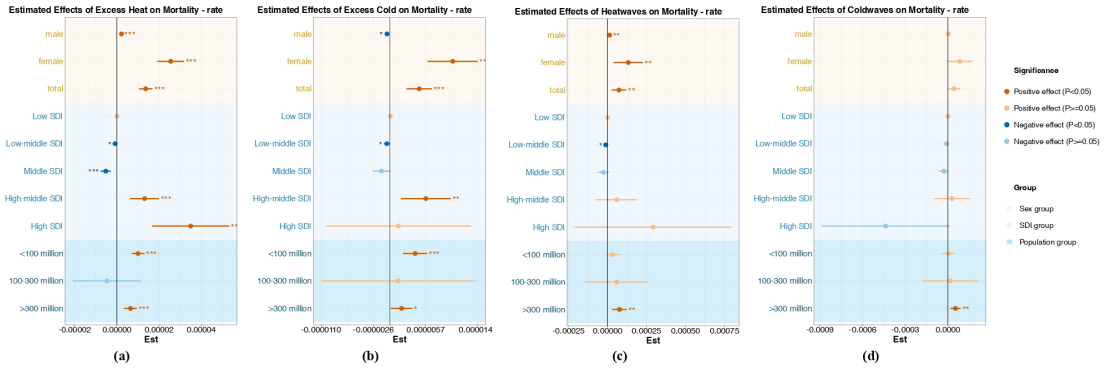


Figure S2. Association between extreme temperatures and the mortality of childhood mental disorders. Forest plots show estimated effects (rate change per 100,000 population) and 95% confidence intervals, stratified by sex, SDI level, and population group. Panels show results for **(a)** excess heat, **(b)** excess cold, **(c)** heatwaves, and **(d)** coldwaves. Asterisks indicate statistical significance (*p < 0.05, **p < 0.01, ***p < 0.001). SDI, Socio−demographic Index.

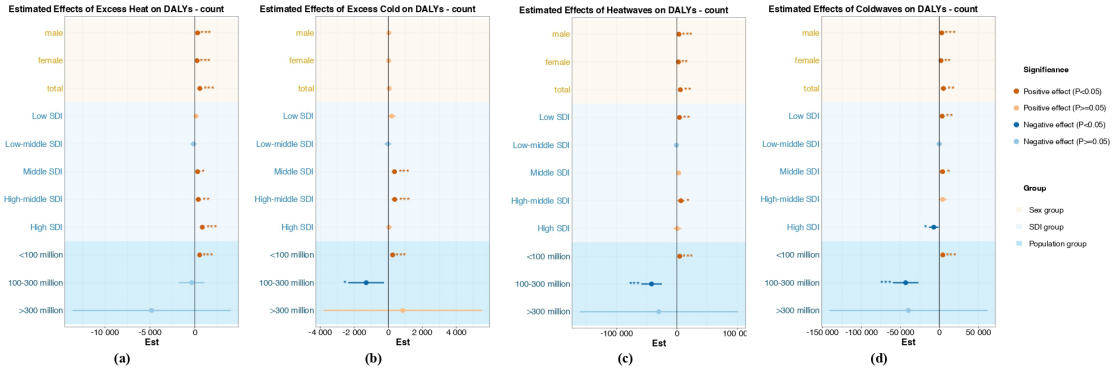


Figure S3. Association between extreme temperatures and the DALYs of childhood mental disorders. Forest plots show estimated effects (rate change per 100,000 population) and 95% confidence intervals, stratified by sex, SDI level, and population group. Panels show results for **(a)** excess heat, **(b)** excess cold, **(c)** heatwaves, and **(d)** coldwaves. Asterisks indicate statistical significance (*p < 0.05, **p< 0.01, ***p< 0.001). DALYs, Disability−Adjusted Life Years. SDI, Socio−demographic Index.

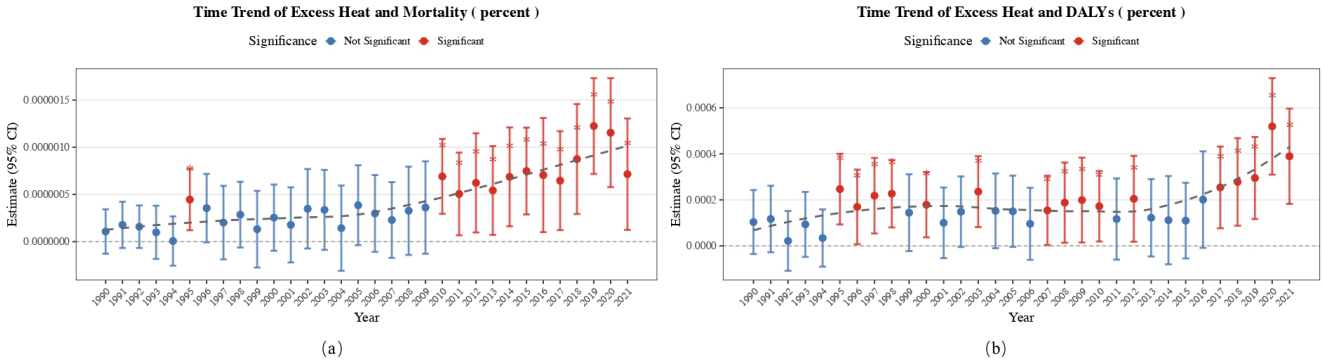


Figure S4. Temporal trends in the impact of excess heat on the burden of childhood mental disorders. Panels show the estimated impact of excess heat on **(a)** mortality rate and **(b)** the percentage of disability–adjusted life years (DALYs).

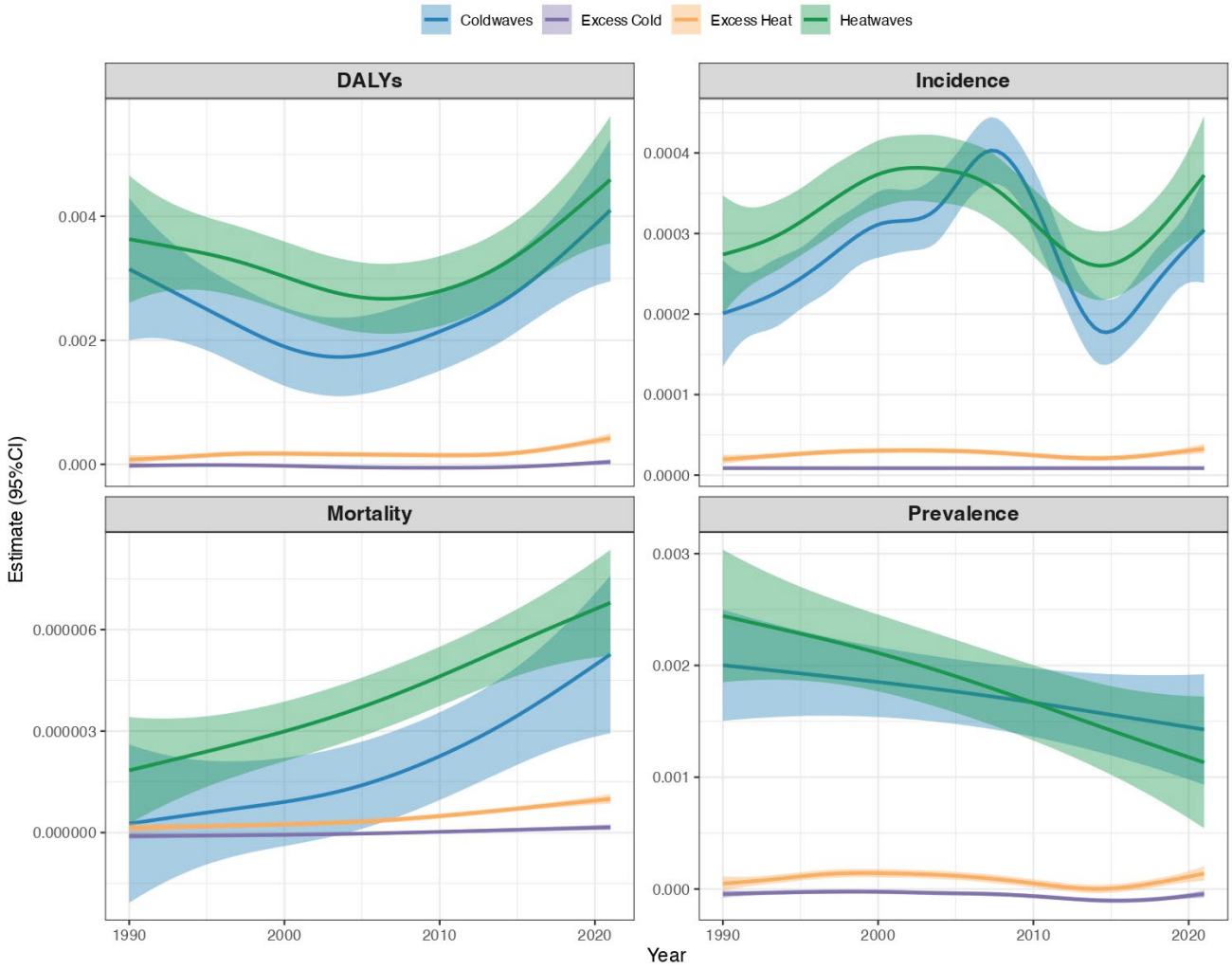


Figure S5. Temporal trends in associations between extreme temperature exposure and childhood mental disorders, 1990–2021. Solid lines represent estimated effects and shaded areas indicate 95% confidence intervals for associations between four types of extreme temperature exposure (excess heat, excess cold, heatwaves, and coldwaves) and childhood mental disorder outcomes, including incidence, prevalence, mortality, and DALYs.