Impact of anomalous temperature on injury mortality in the USA

Robbie Parks

Global Environmental Health

Figures

Figure 1

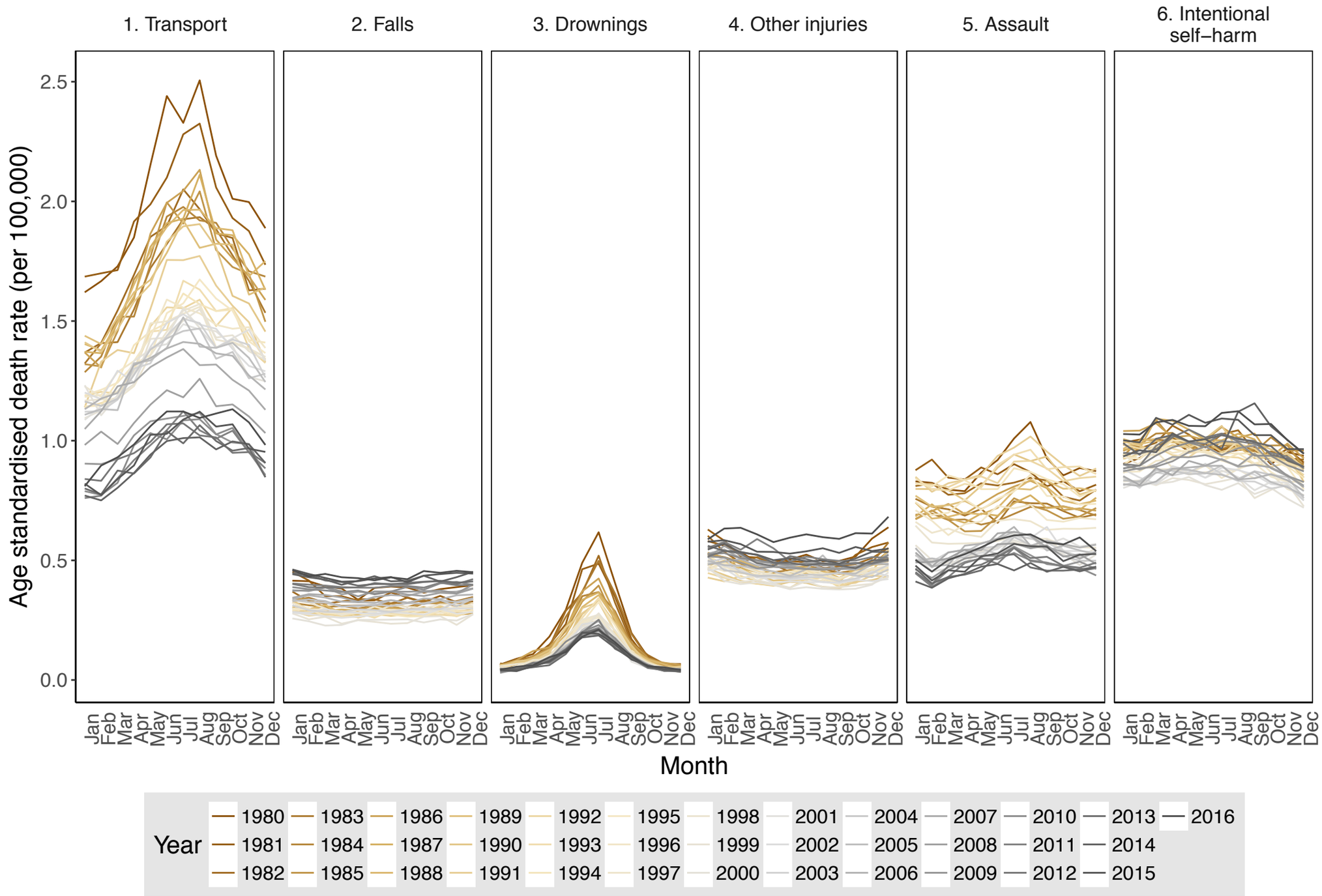

1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm
Age standardised death rate (per 100,000)
2.5
2.0
1.5
1.0
0.5
0.0
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
Year
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Figure 2

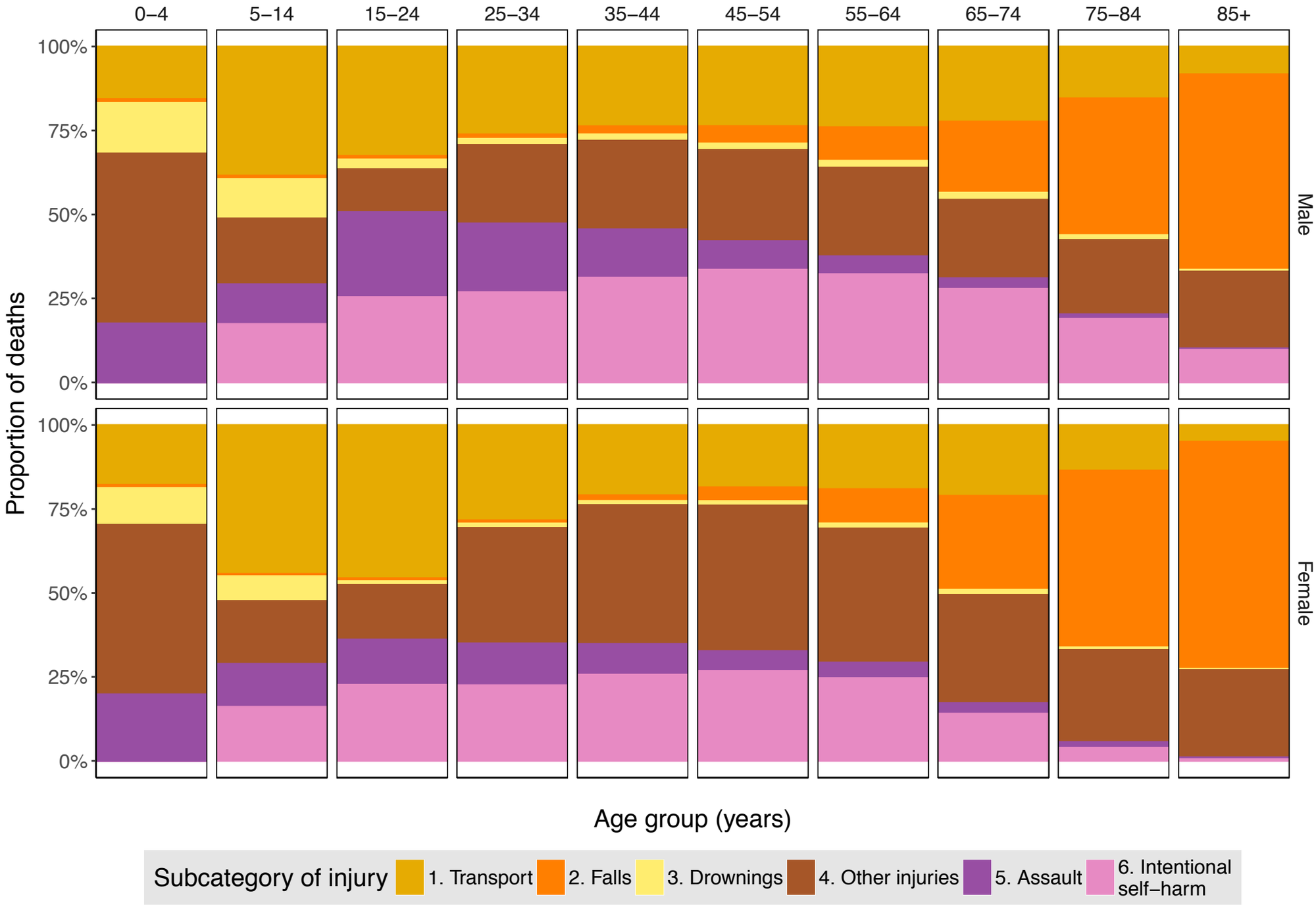

0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
100%
75%
50%
25%
0%
Proportion of deaths
Male
Female
Age group (years)
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self–harm

Figure 3

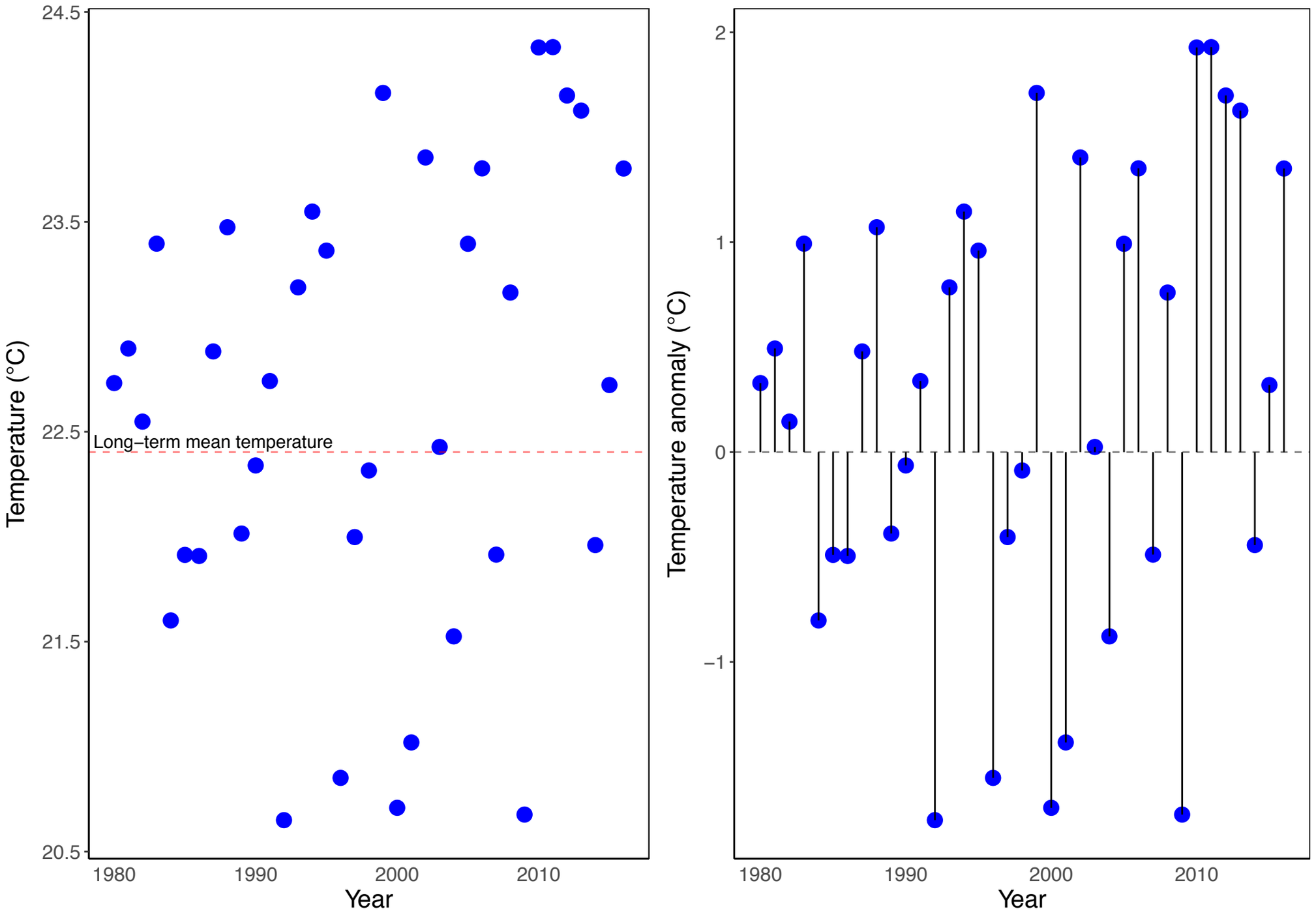

24.5
23.5
22.5
21.5
20.5
Long−term mean temperature
Temperature (°C)
1980
1990
2000
2010
Year
2
1
0
−1
Temperature anomaly (°C)
1980
1990
2000
2010
Year

Figure 4

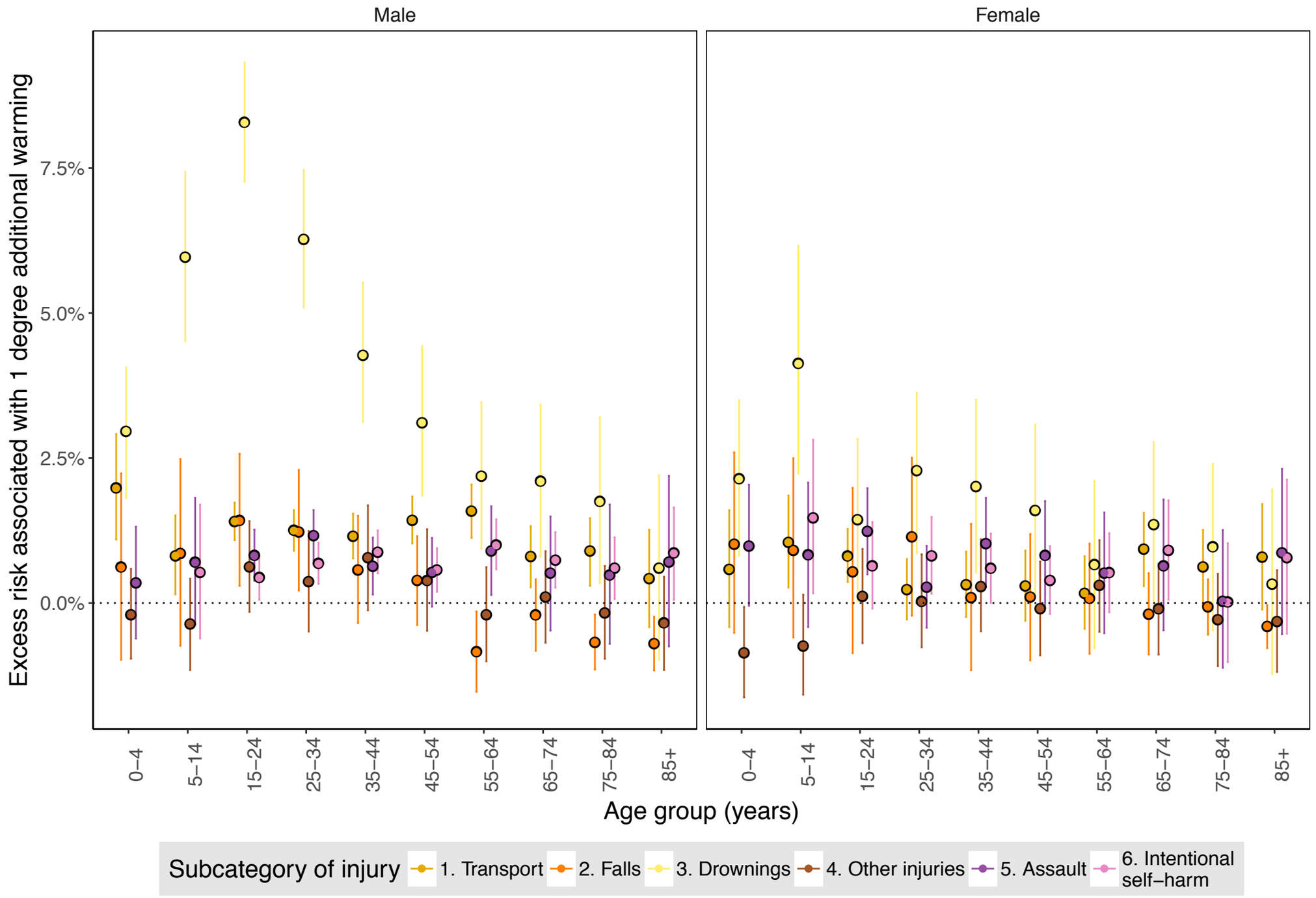
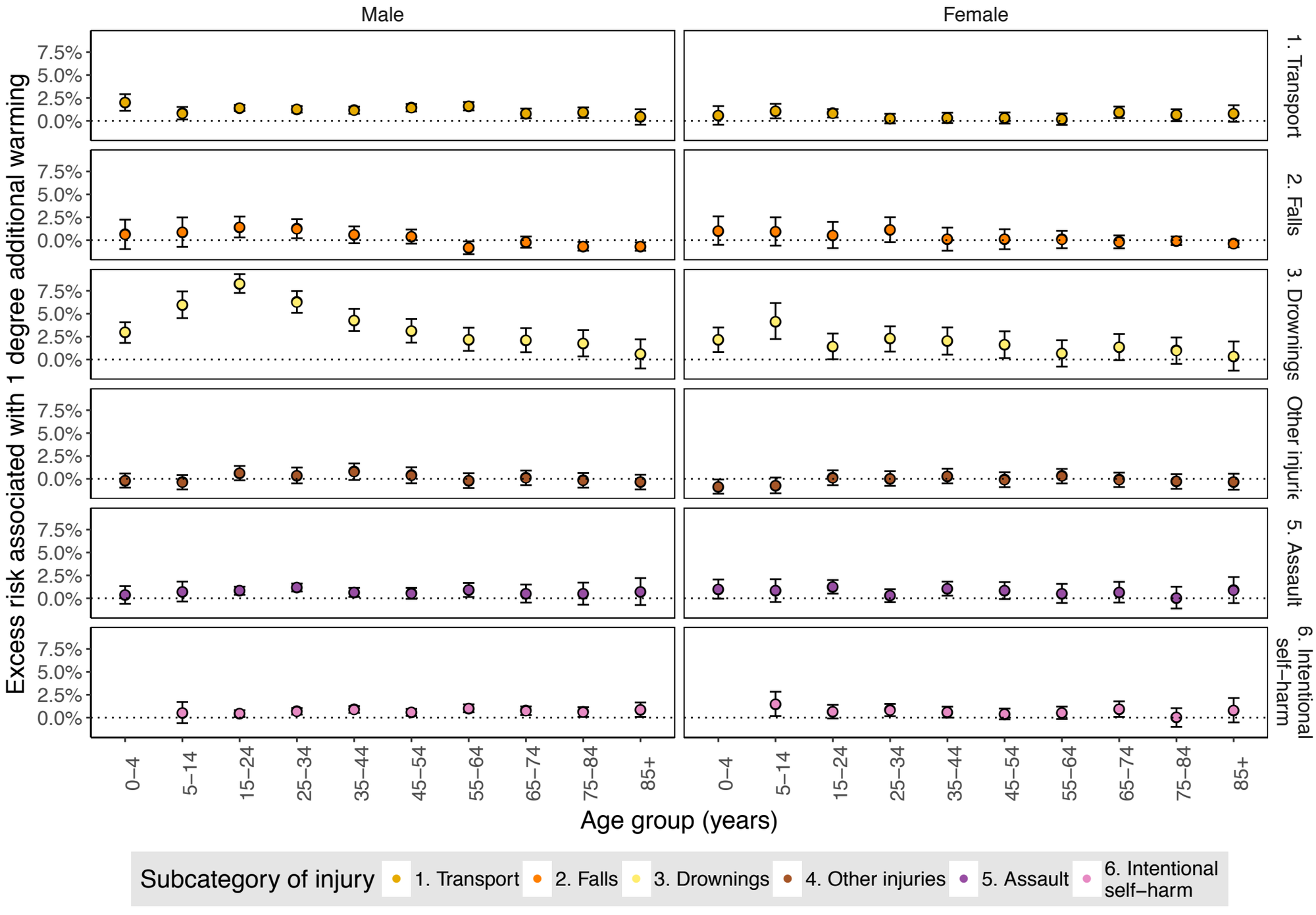

Male
Female
Excess risk associated with 1 degree additional warming
7.5%
5.0%
2.5%
0.0%
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self–harm

Figure 4


Male
Female
Excess risk associated with 1 degree additional warming
7.5%
5.0%
2.5%
0.0%
1. Transport
2. Falls
3. Drownings
Other injurie
5. Assault
6. Intentional self–harm
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
Subcategory of injury
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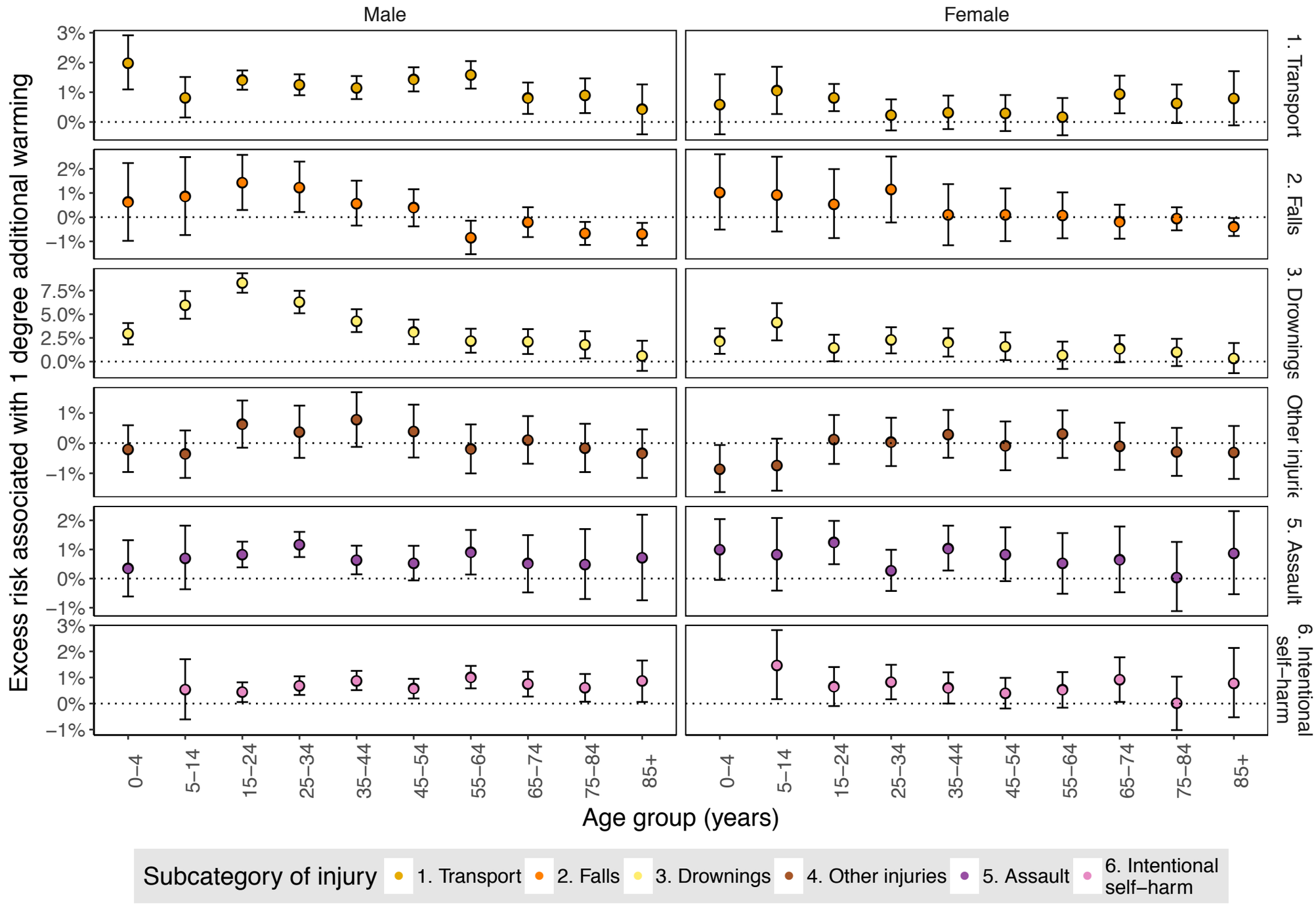
6. Intentional self–harm

Figure 4 (alt)


Male
Female
Excess risk associated with 1 degree additional warming
1. Transport
2. Falls
3. Drownings
Other injurie
5. Assault
6. Intentional self–harm
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
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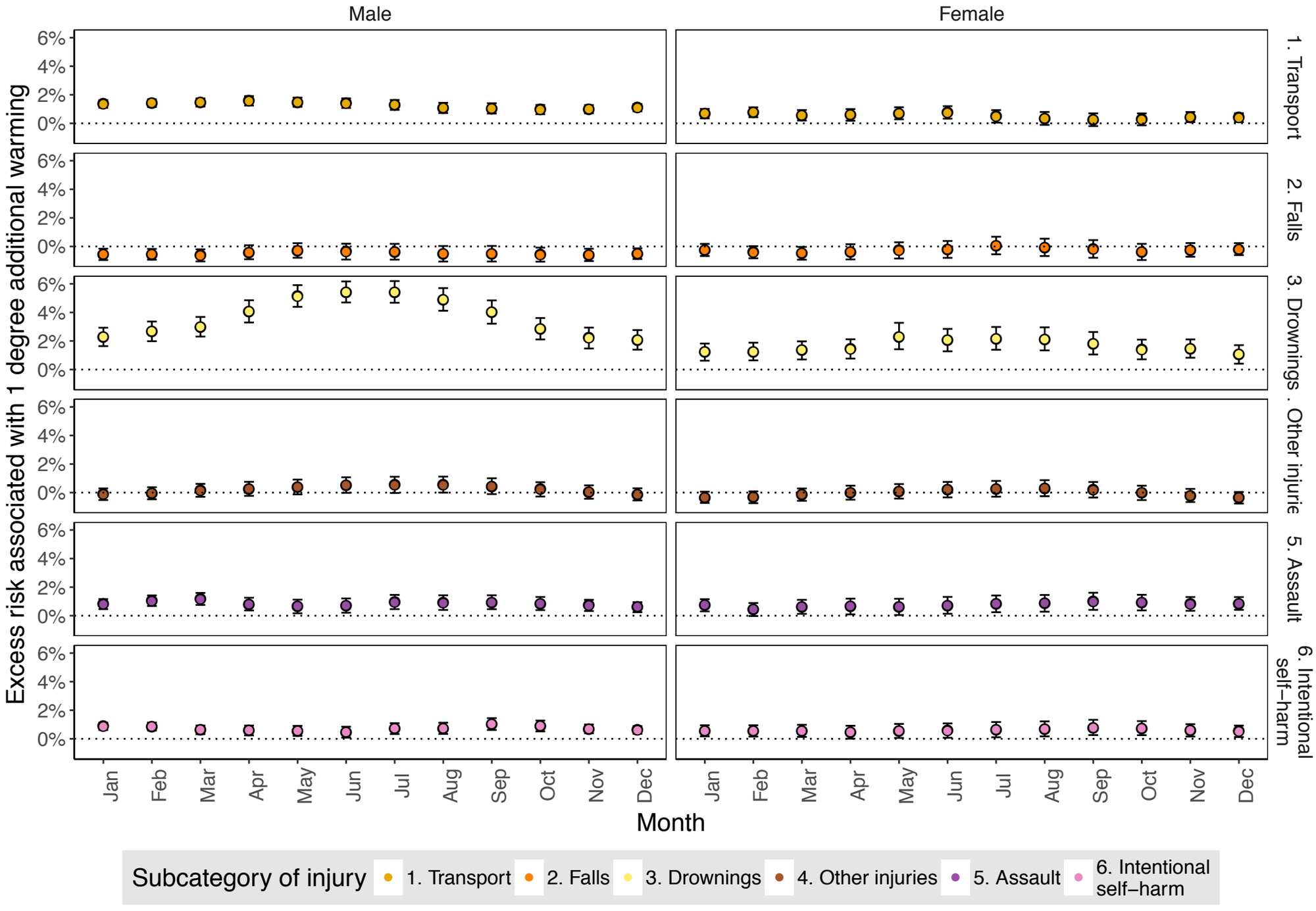
Male
Female
Excess risk associated with 1 degree additional warming
6%
4%
2%
0%
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
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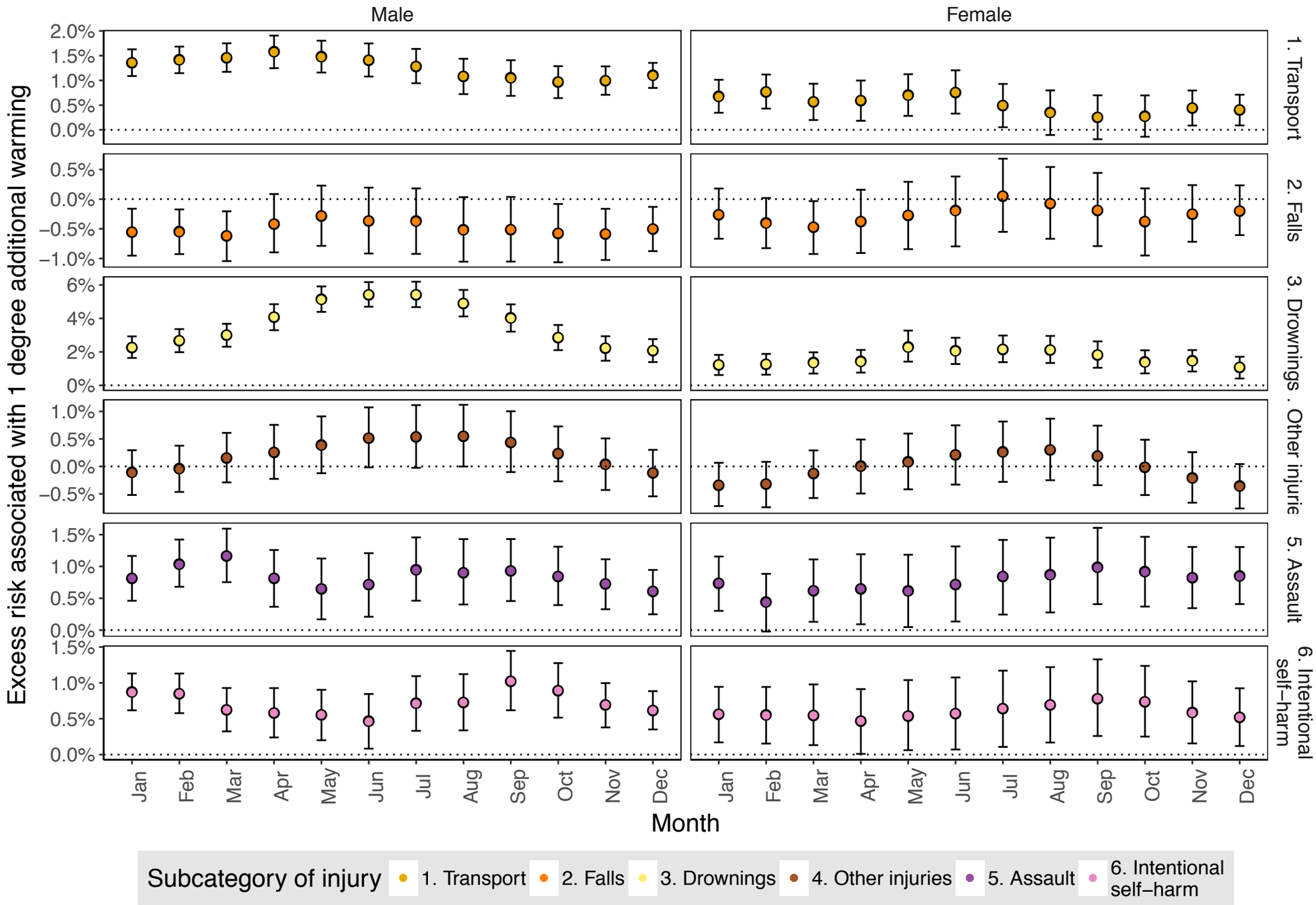
Male
Female
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm
Excess risk associated with 1 degree additional warming
2.0%
1.5%
1.0%
0.5%
0.0%
−0.5%
−1.0%
6%
4%
2%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of injury
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2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm

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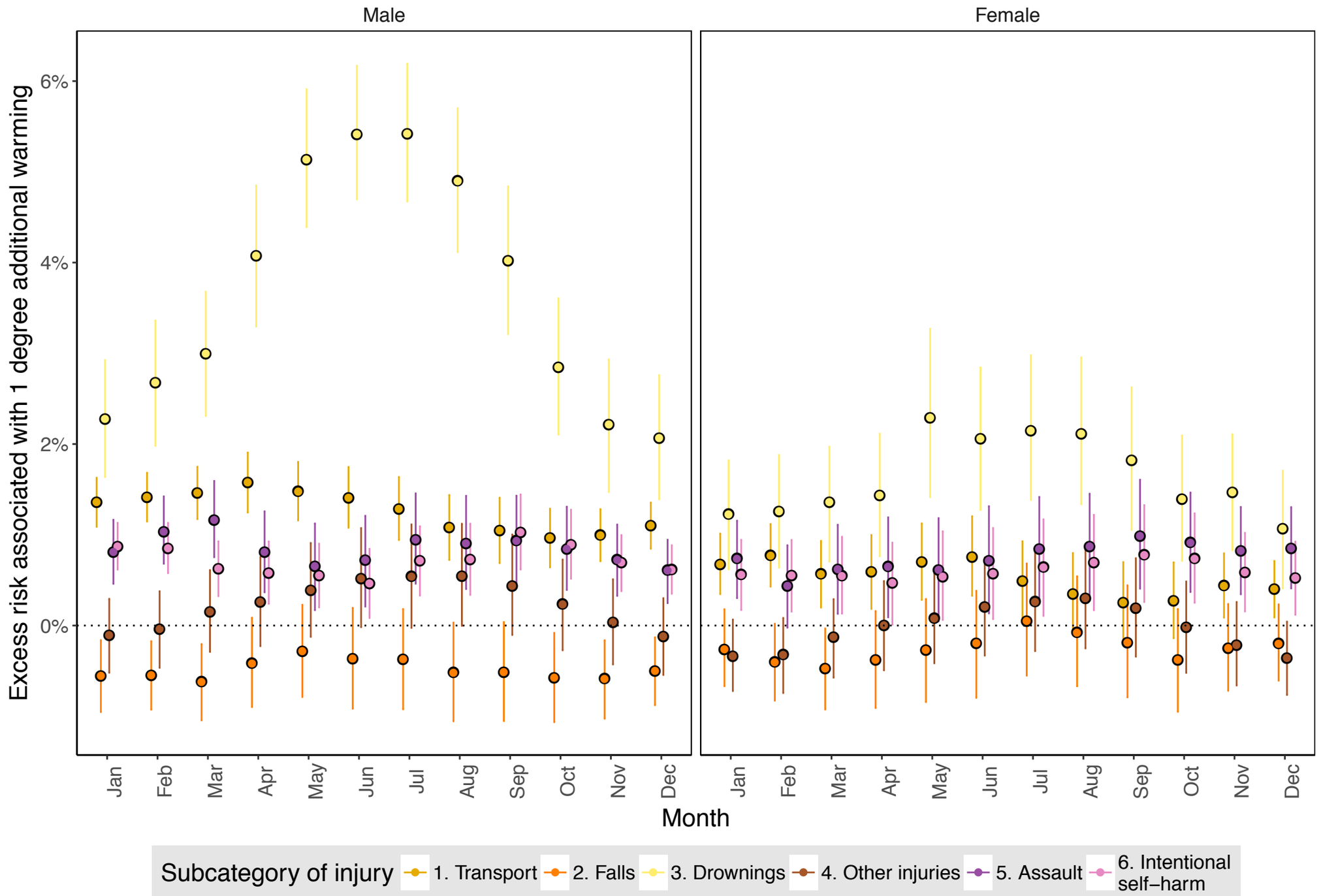

Male
Female
Excess risk associated with 1 degree additional warming
6%
4%
2%
0%
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm

Figure 5

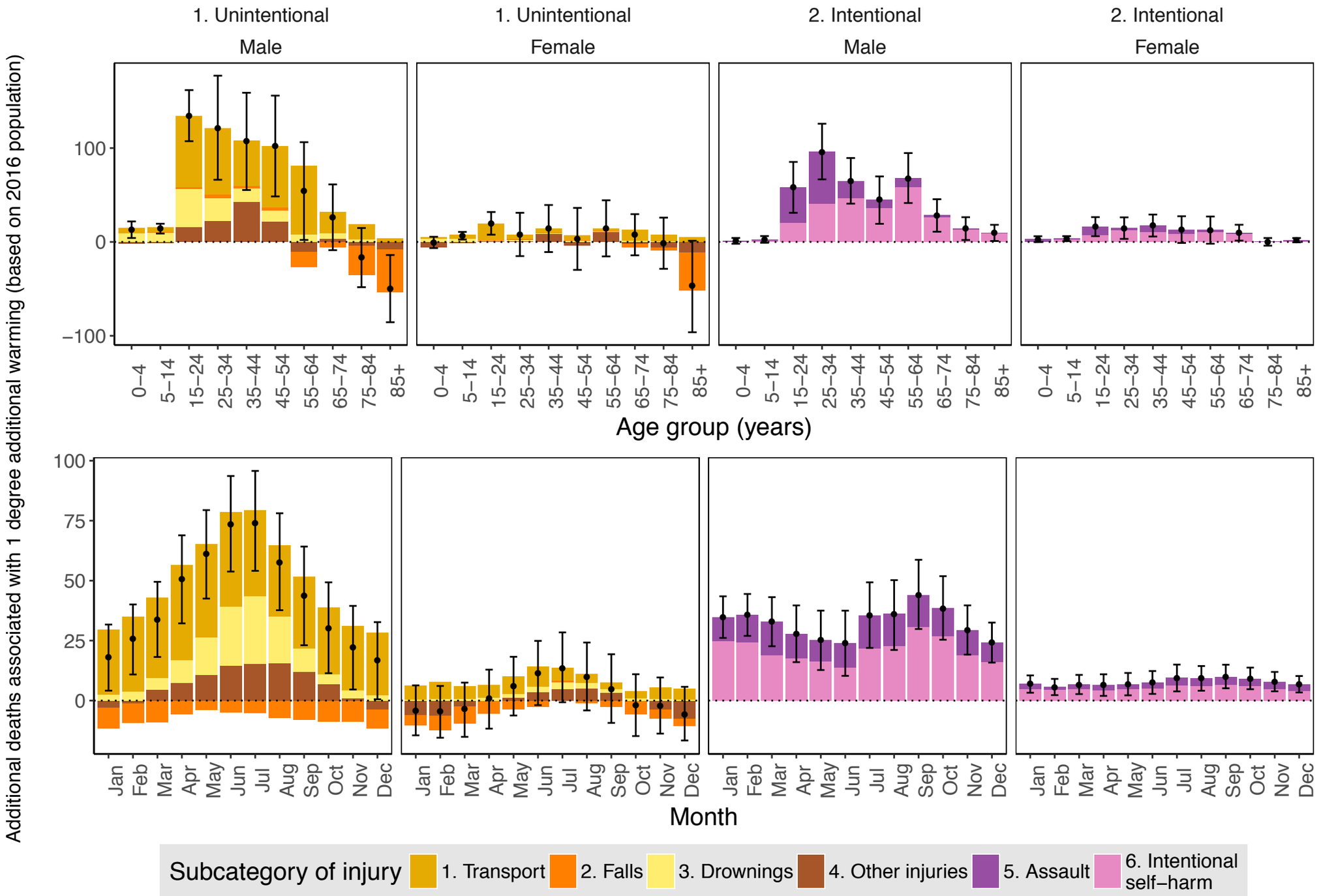

1. Unintentional
Male
1. Unintentional
Female
2. Intentional
Male
2. Intentional
Female
Additional deaths associated with 1 degree a
100
0
−100
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm

Figure 5 (alt)

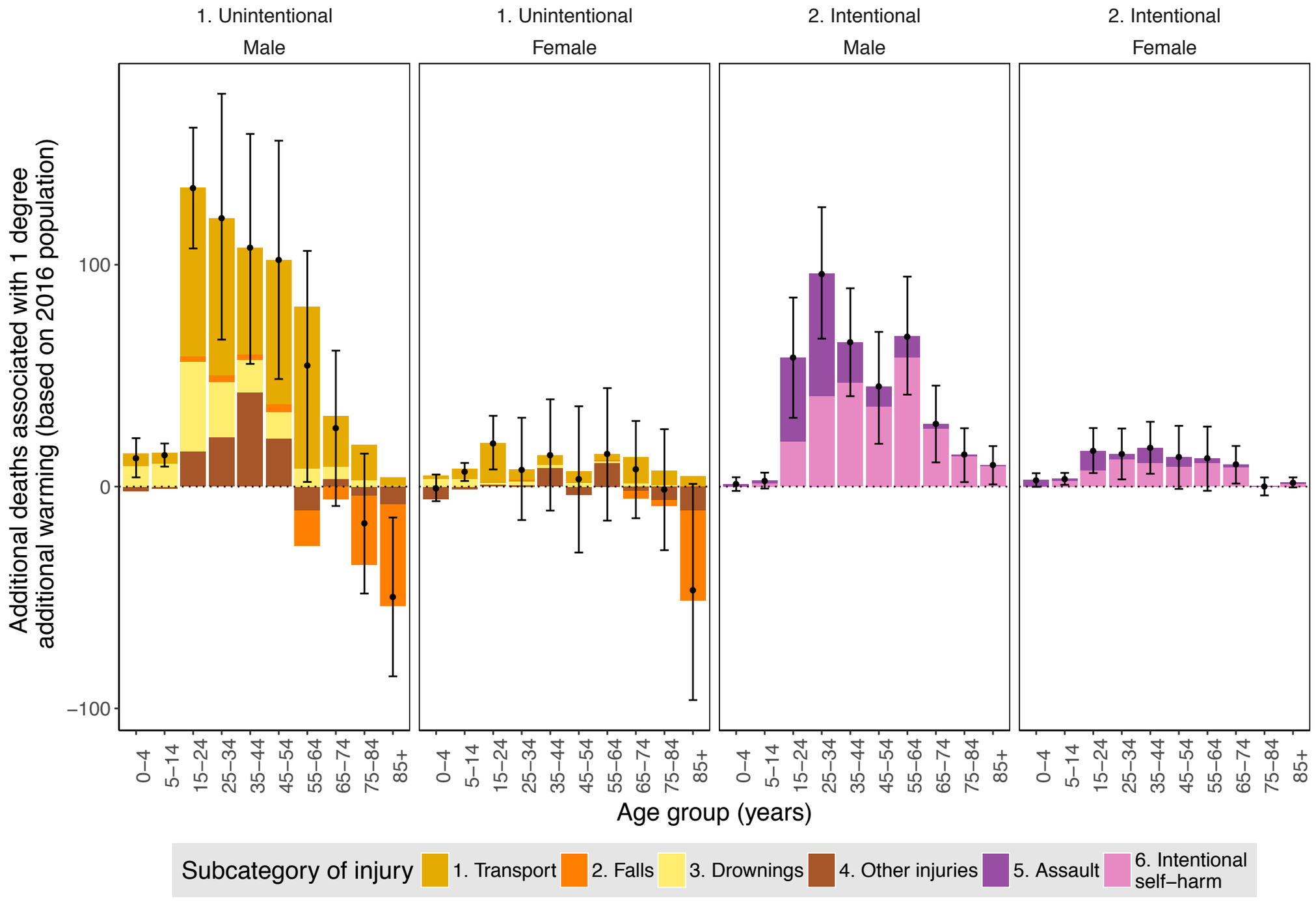
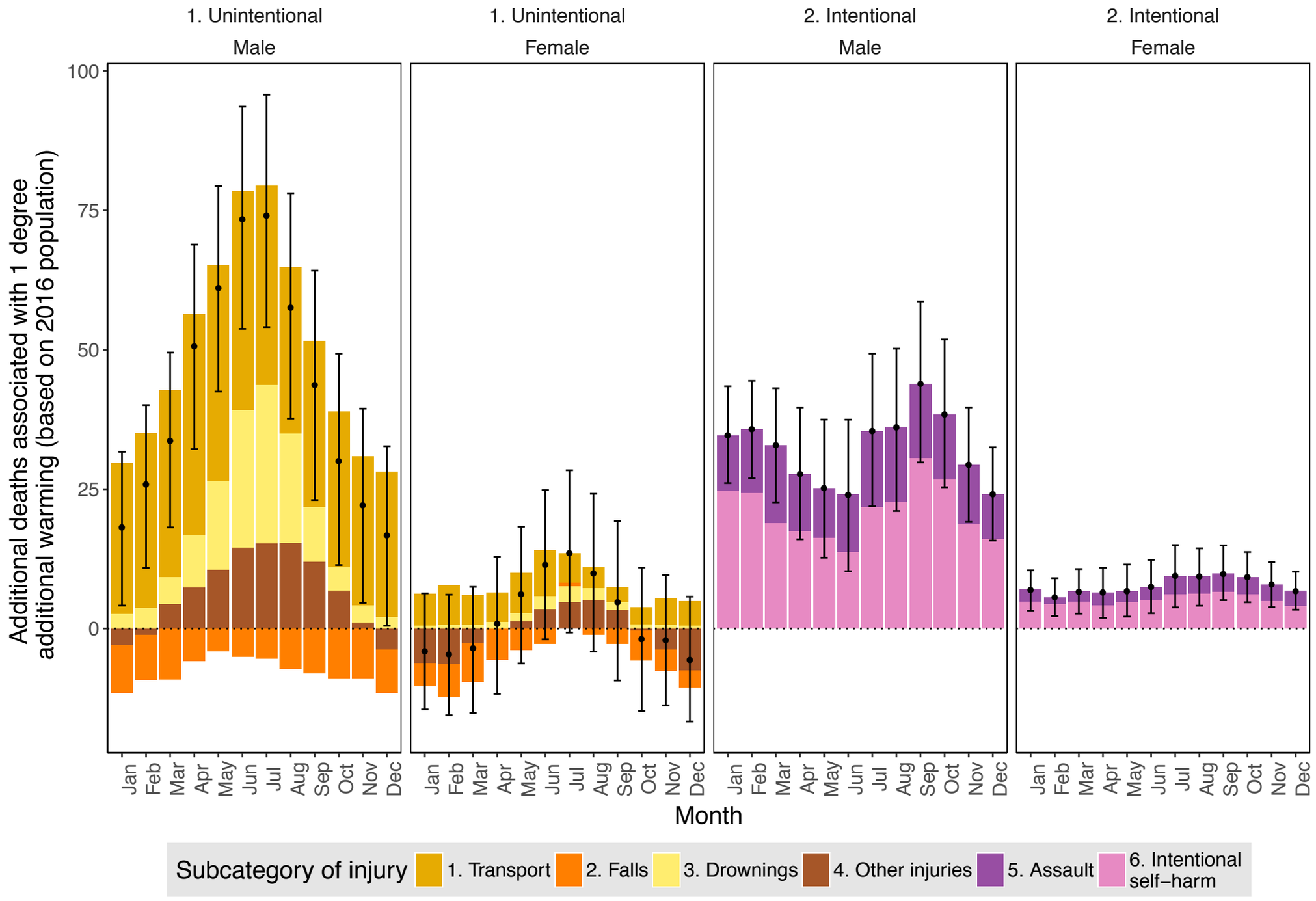

1. Unintentional
Male
1. Unintentional
Female
2. Intentional
Male
2. Intentional
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
100
0
−100
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm

Figure 5 (alt)


1. Unintentional
Male
1. Unintentional
Female
2. Intentional
Male
2. Intentional
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of injury
1. Transport
2. Falls
3. Drownings
4. Other injuries
5. Assault
6. Intentional self−harm

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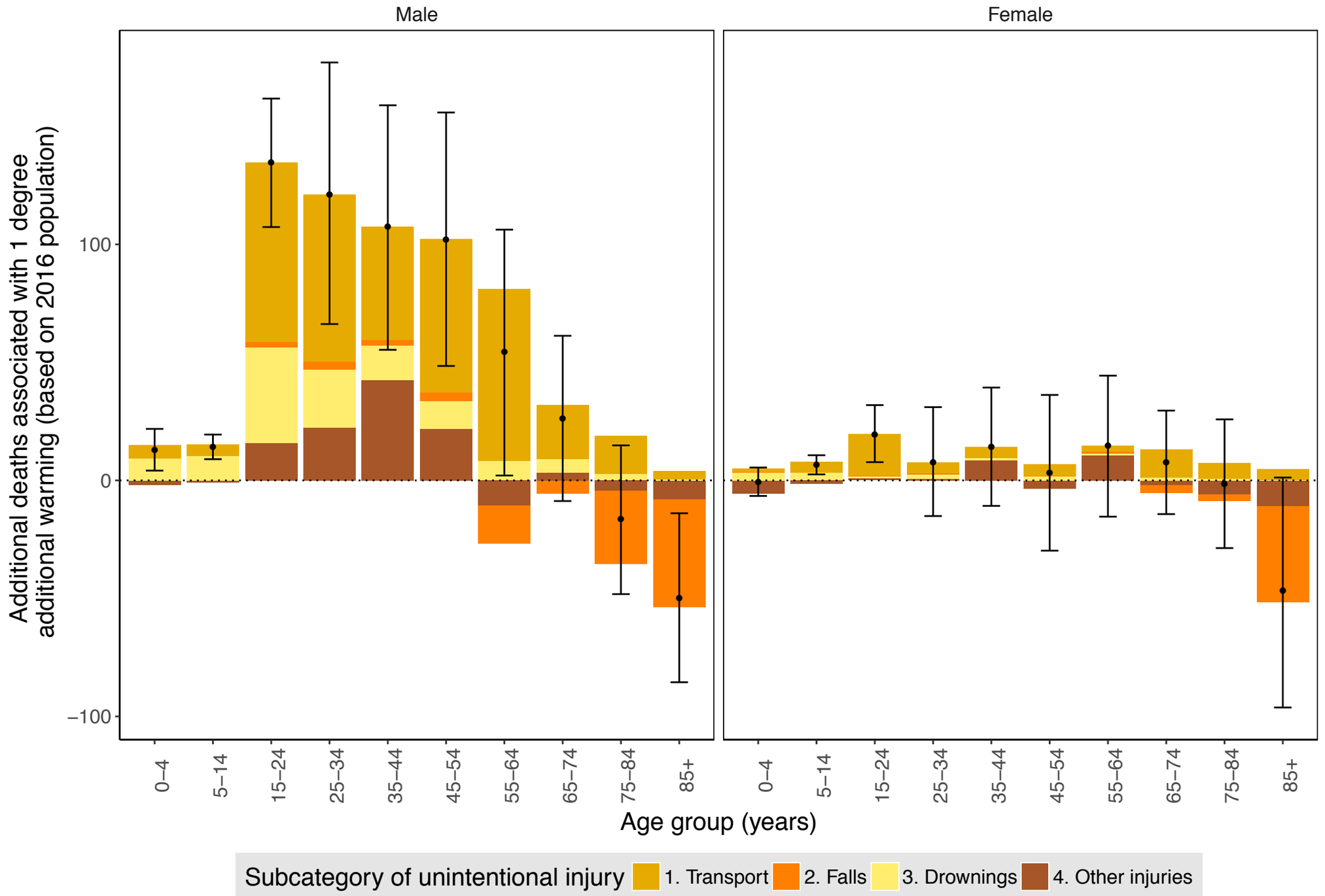

Male
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
100
0
−100
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
Subcategory of unintentional injury
1. Transport
2. Falls
3. Drownings
4. Other injuries

Figure 5 (alt)

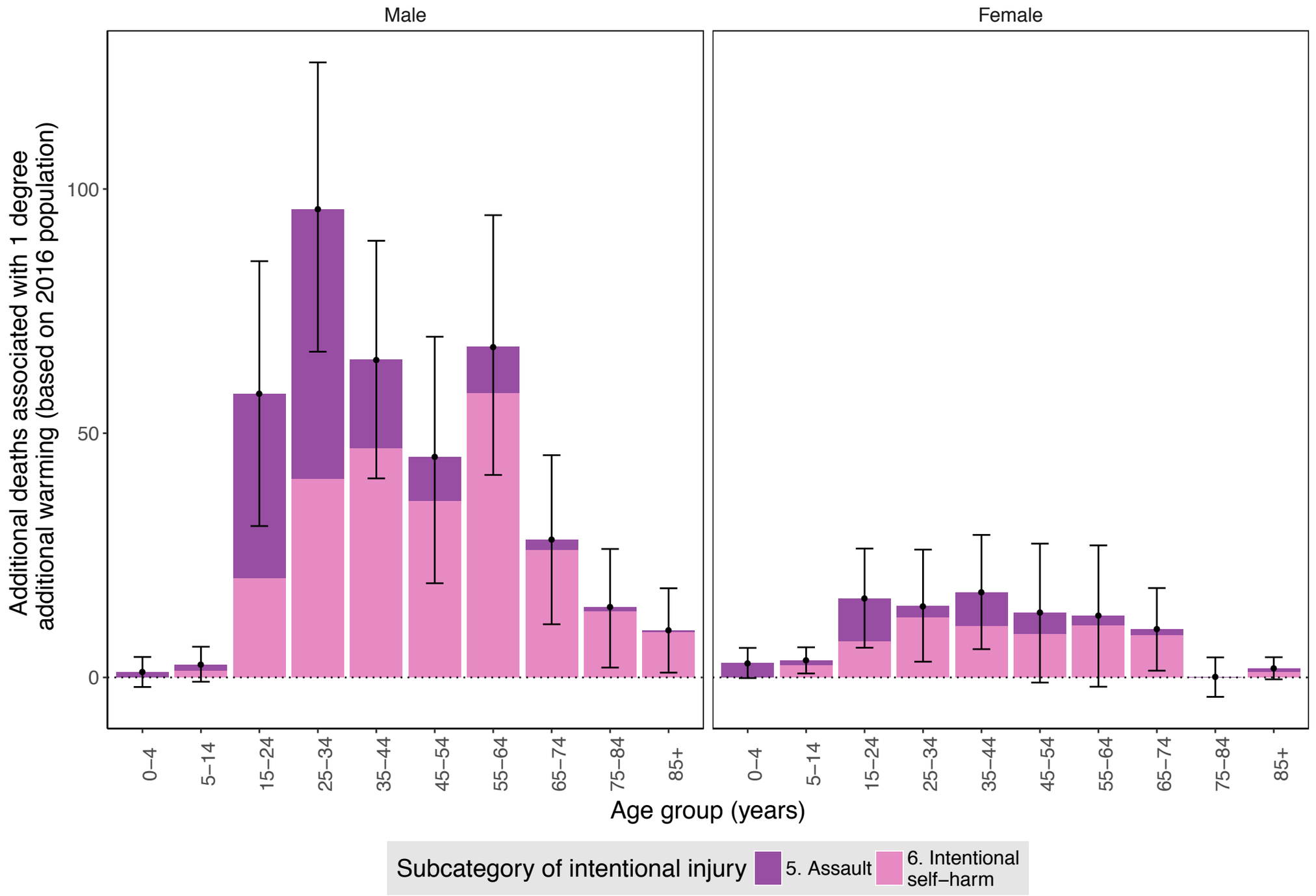

Male
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
100
50
0
0–4
5–14
15–24
25–34
35–44
45–54
55–64
65–74
75–84
85+
Age group (years)
Subcategory of intentional injury
5. Assault
6. Intentional self–harm

Figure 5 (alt)

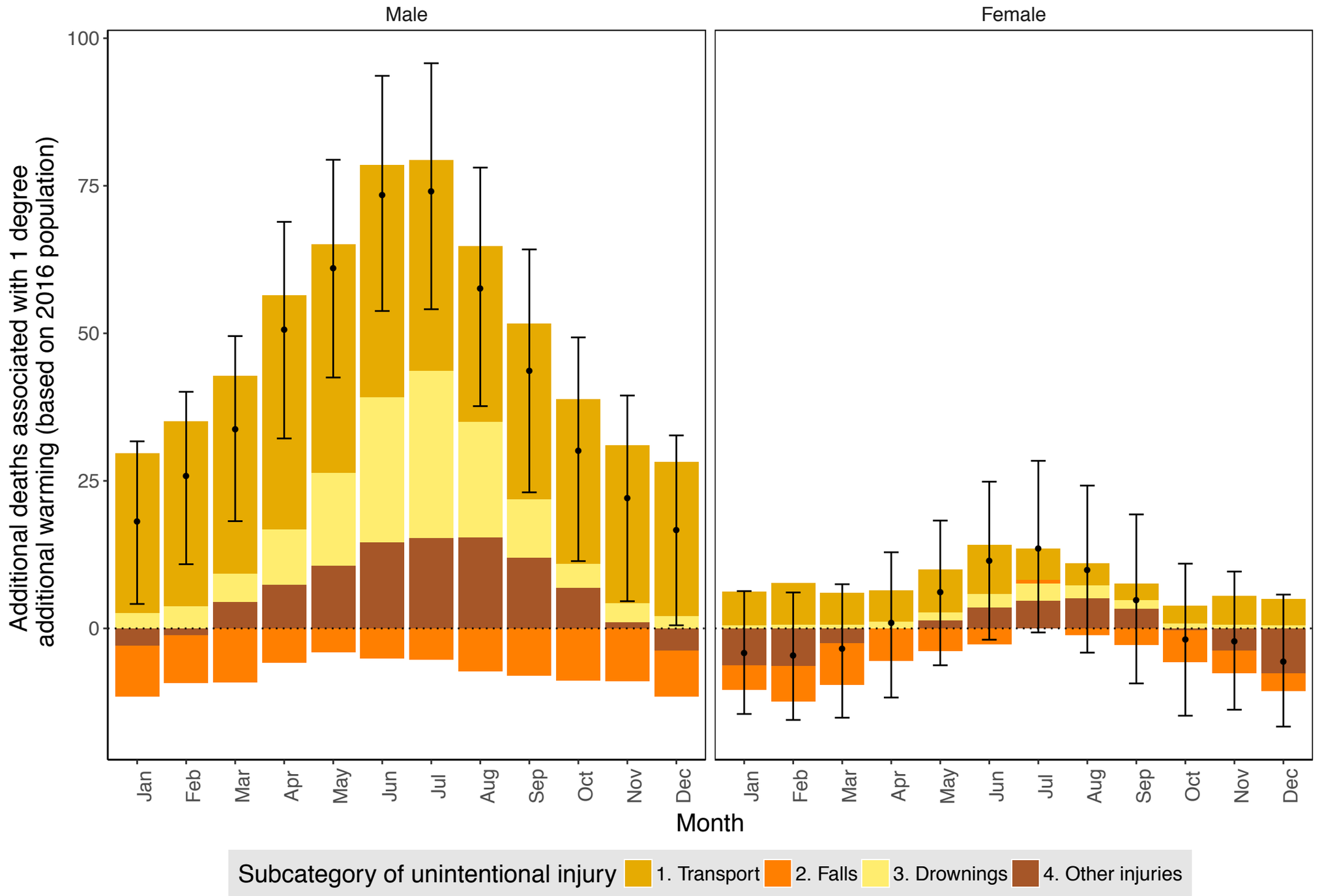
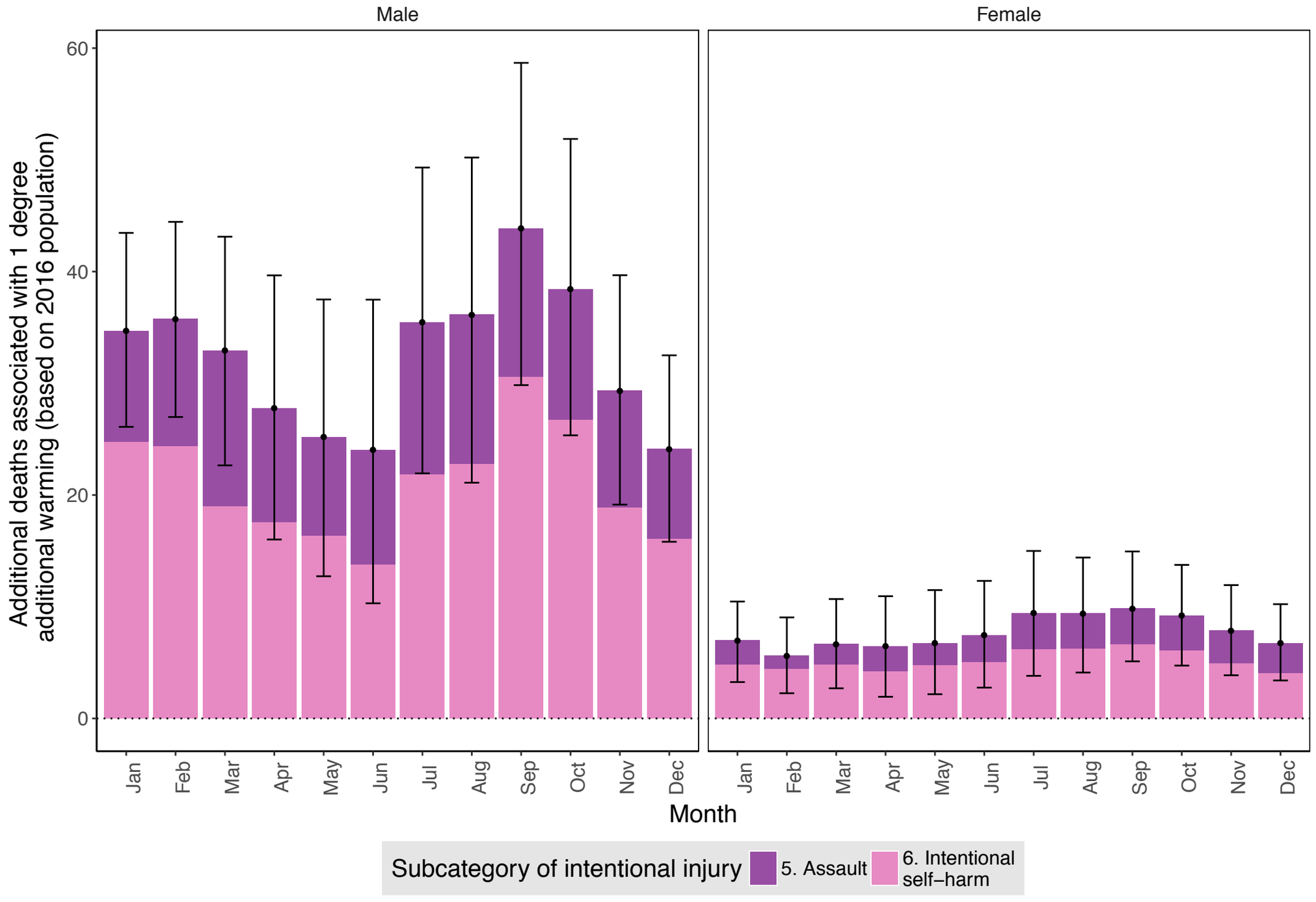

Male
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
100
75
50
25
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of unintentional injury
1. Transport
2. Falls
3. Drownings
4. Other injuries

Figure 5 (alt)


Male
Female
Additional deaths associated with 1 degree additional warming (based on 2016 population)
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Subcategory of intentional injury
5. Assault
6. Intentional self−harm

Model comparison

Model: Overview

- Bayesian spatiotemporal model implemented in R-INLA.
- Death counts modelled in a single age-sex group during a particular month m, per state s, at time t by:

$$\text{Deaths}_{[m,s,t]} \sim \text{Poisson}(\text{Population}_{[m,s,t]}.\text{Death rates}_{[m,s,t]})$$

- $\text{Death rates}_{[m,s,t]}$ modelled via log-link function:

$$\begin{aligned}\log(\text{Death rates}_{[m,s,t]}) =& (\alpha_0 + \beta_0.t) \\ &+(\alpha_m + \beta_m.t) \\ &+(\alpha_s + \beta_s.t) \\ &+\gamma_m.\text{Anomaly}_{m,s,t} \\ &+\xi_{m,s} \\ &+\pi_t+ \\ &+\epsilon_{m,s,t}\end{aligned}$$

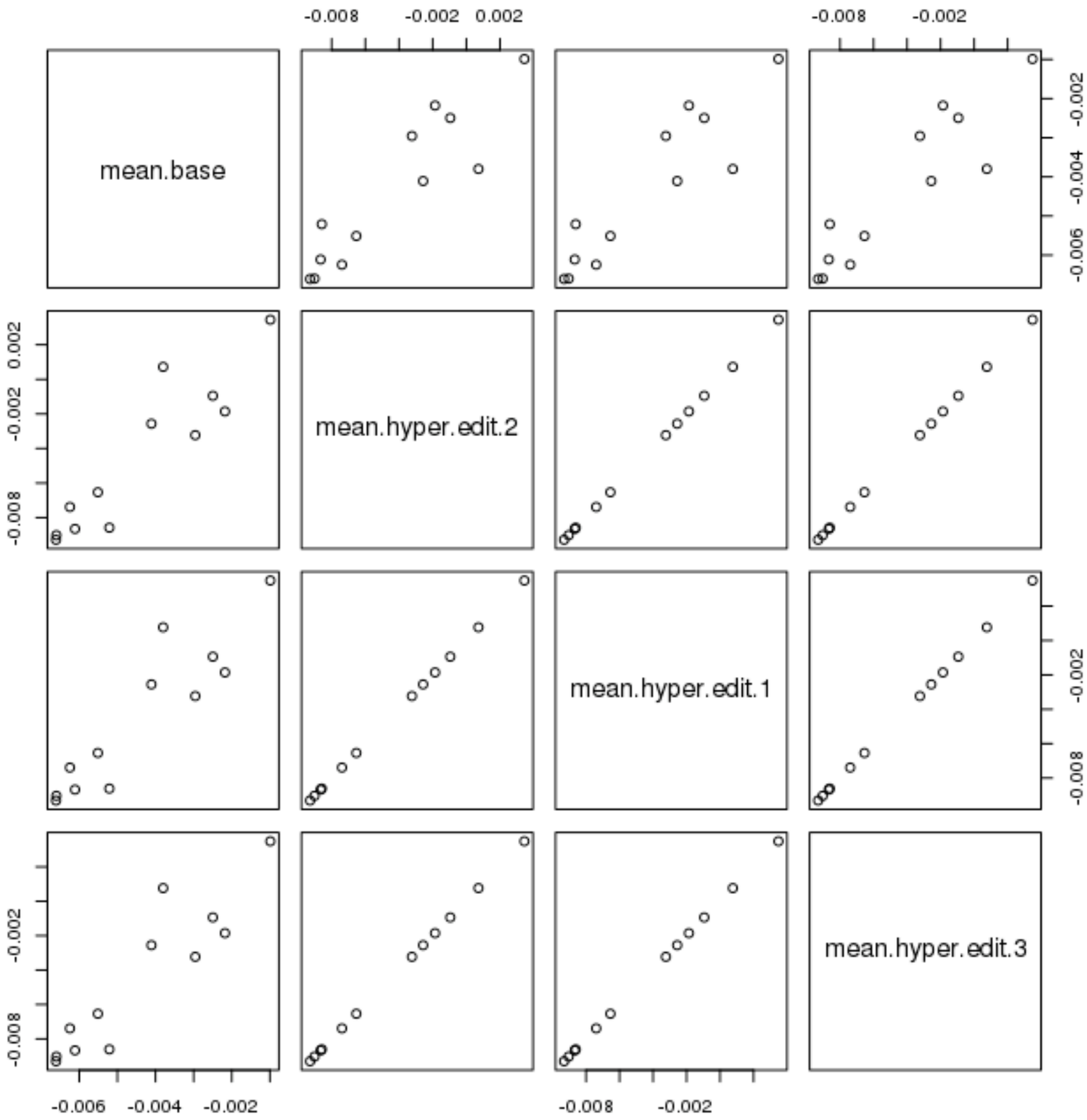
where:
α = intercepts, β = time-slopes, γ = temperature effects,
ξ = state-month interaction, π = random walk over time,
ϵ = overdispersion.
Anomaly = Temperature anomaly term (see Fig. 3)

Global Environmental Health

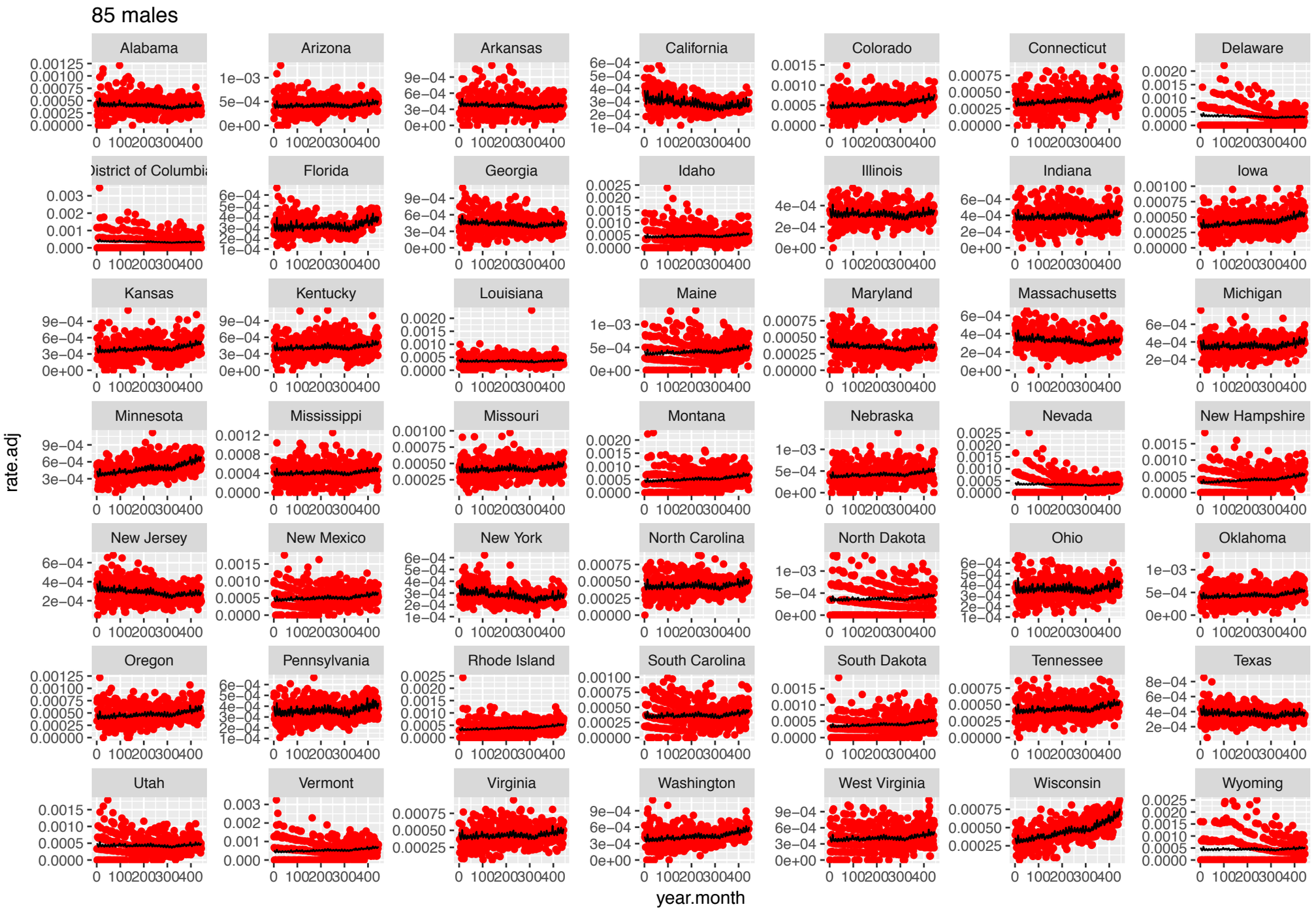
Models

Model	Global Intercept	Global Slope	Month-specific intercept	Month-specific slope	State-specific intercept	State-specific slope	State-month specific intercept	State-month specific slope	Month-specific ANOMALY	RW1 over time	Overdispersion
Base	Y	Y	Cyclic RW1	Cyclic RW1	Besag	Besag	Cyclic RW1 (Besag)	Cyclic RW1 (Besag)	Cyclic RW1	National	Y
Hyper edit 1	Y	Y	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit only RW1)	Cyclic RW1 (hyper edit only RW1)	Cyclic RW1	National	Y
Hyper edit 2	Y	Y	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edits fixed=FALSE)	Cyclic RW1 (hyper edits fixed=FALSE)	Cyclic RW1	National	Y
Hyper edit 3	Y	Y	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edit)	Cyclic RW1 (hyper edits fixed=TRUE)	Cyclic RW1 (hyper edits fixed=TRUE)	Cyclic RW1	National	Y
Simple 1	Y	Y			IID	IID				National	Y
Simple 2	Y	Y			IID	IID				State-specific	Y

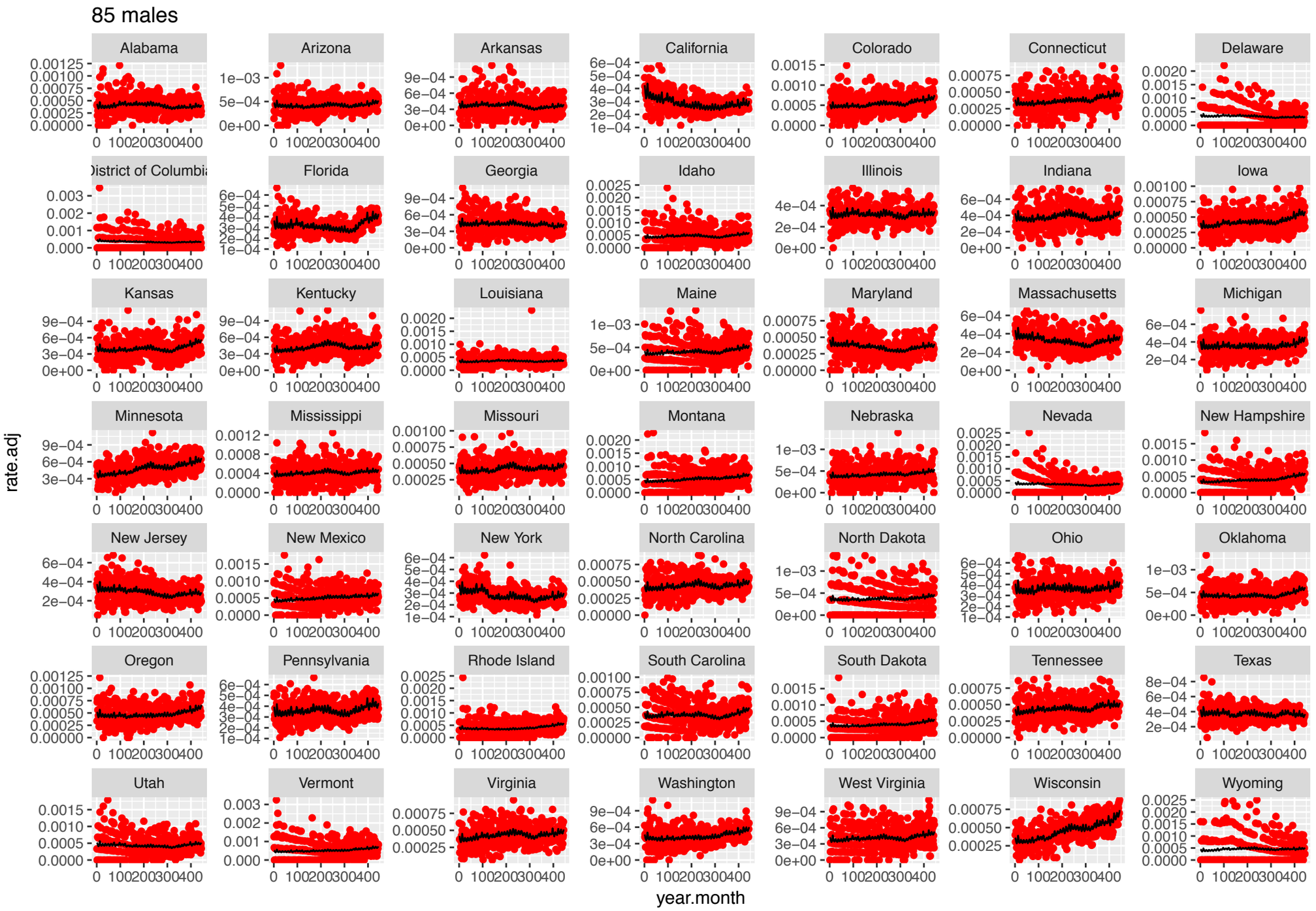
How does changing priors affect anomaly term?



How does having a state-specific RW1 over time affect fit? National RW1 over time



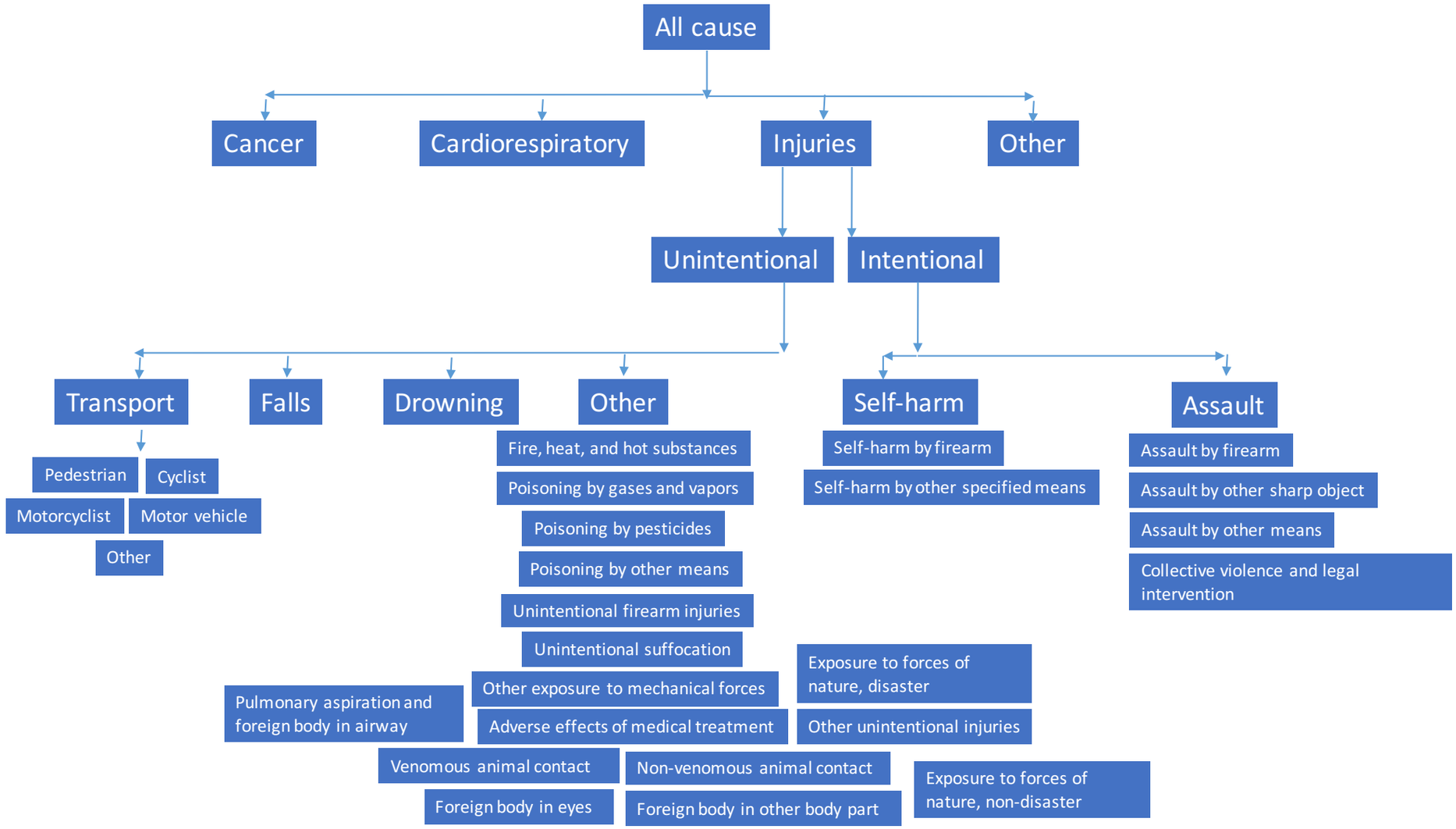
How does having a state-specific RW1 over time affect fit? State RW1 over time



Background

Mortality data: Overview

- 5.8 million injury deaths in contiguous USA 1980-2016
- Injury cause of death categories:



Global Environmental Health

Mortality data: Overview

- 5.8 million injury deaths in contiguous USA 1980-2016
- Injury cause of death categories:

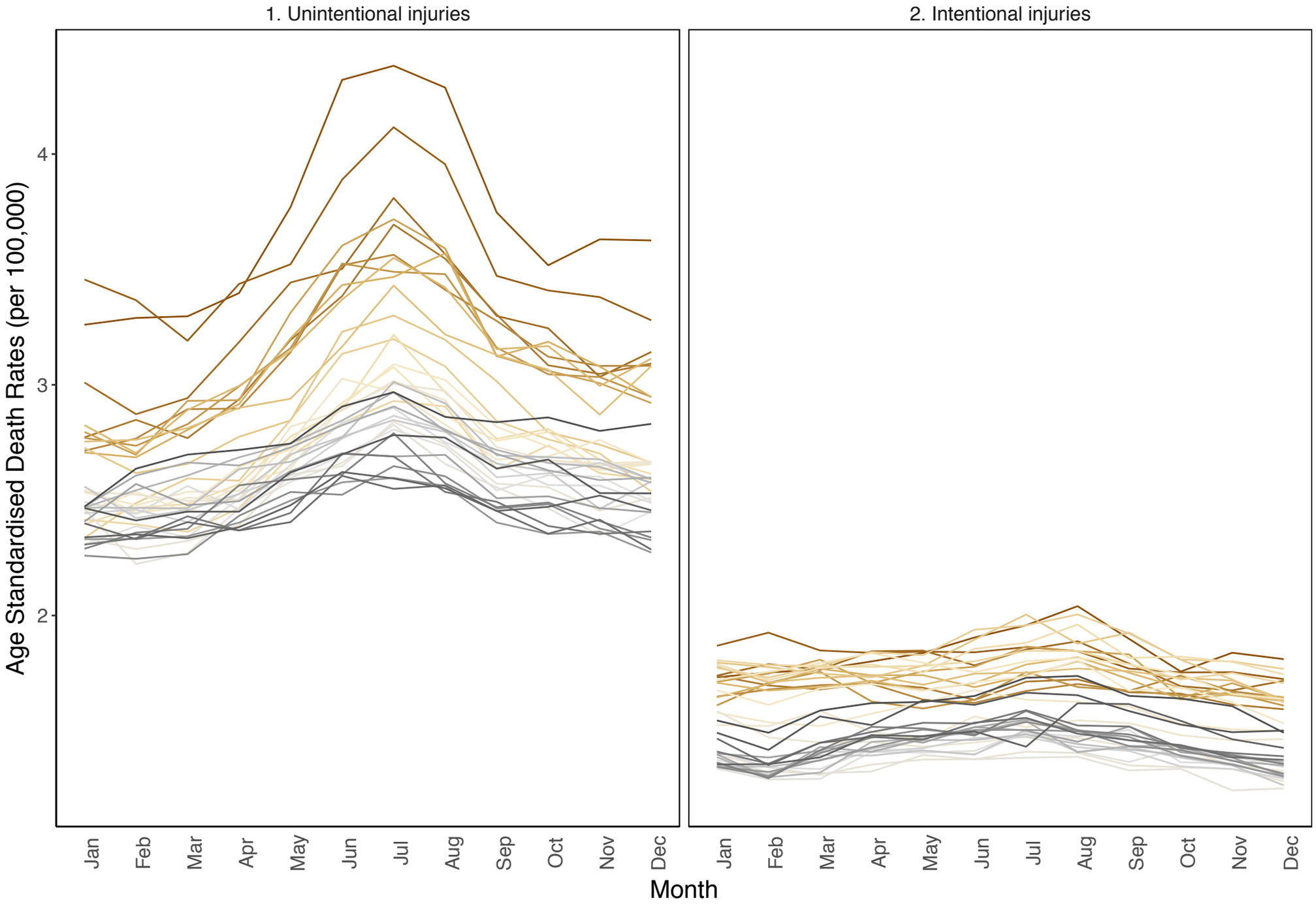
Cause			Male	Female	Total
Unintentional			2,470,093	1,340,723	**3,810,816**
	Transport		1,186,839	498,661	1,685,500
	Falls		337,946	322,662	660,608
	Drowning		112,023	29,246	141,269
	Other		833,285	490,154	1,323,439
Intentional			1,536,361	417,138	**1,953,499**
	Assault		582,220	162,517	744,737
	Intentional self-harm		954,141	254,621	1,208,762
					5,764,315

Mortality data: Overview

- 5.8 million injury deaths in contiguous USA 1980-2016
- Injury cause of death categories:

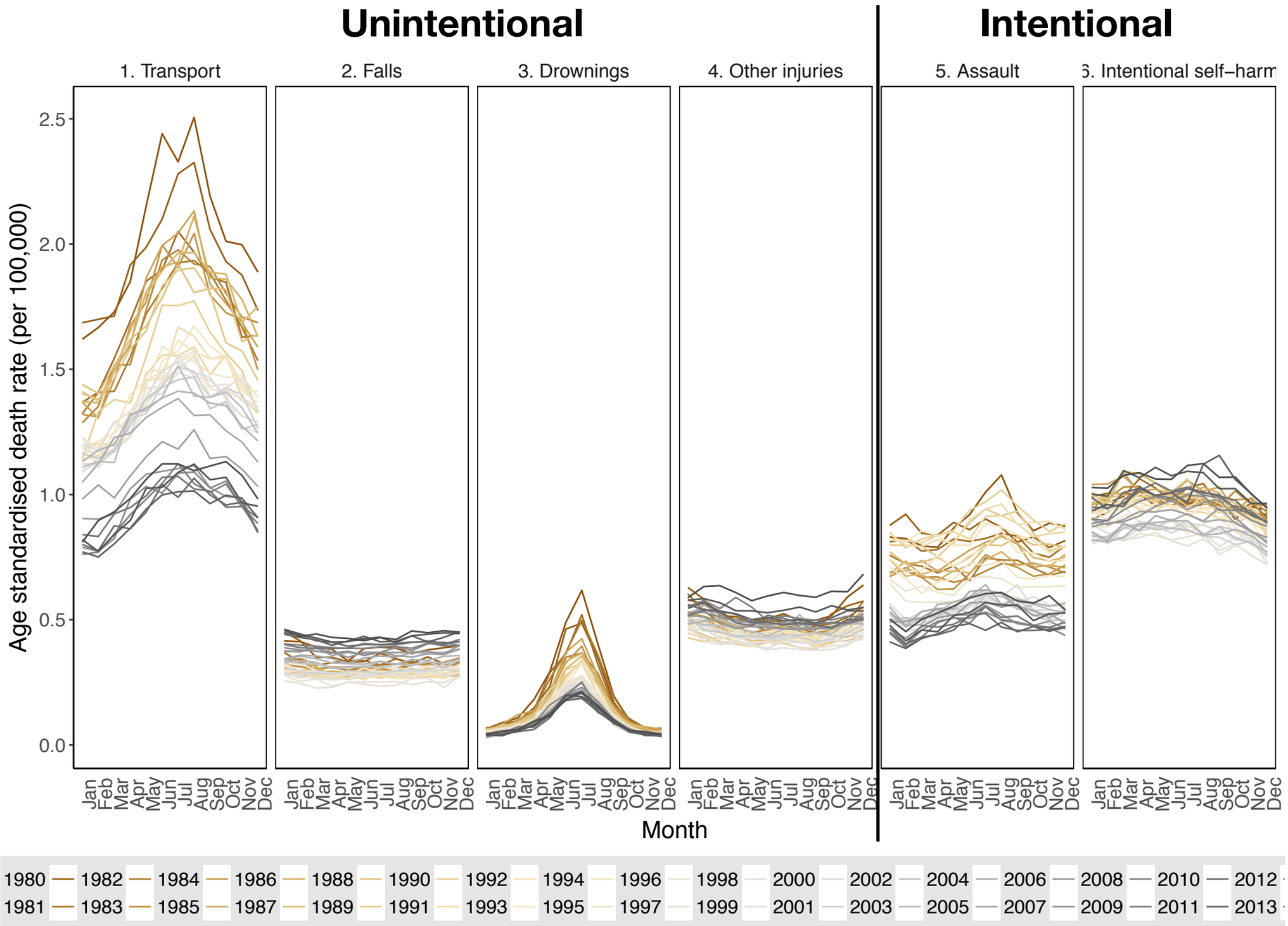
Age	Male						Female					
	Transport	Falls	Drowning	Intentional self-harm	Assault	Other	Transport	Falls	Drowning	Intentional self-harm	Assault	Other
0-4	18973	1813	13801	0	13795	35806	15104	1030	7343	0	11106	24914
5-14	42118	1305	10991	7398	8821	20905	25546	478	3454	2803	5772	10087
15-24	311828	8616	25936	142475	178936	80019	112795	1345	2706	28131	32994	21523
25-34	237642	12297	18055	176812	168154	132277	73841	2044	2664	41543	39082	43518
35-44	171656	17008	13314	169713	99288	142988	62711	3864	2670	52059	29208	60060
45-54	140108	25856	10600	156675	56578	124209	53456	7973	2638	53932	17457	66192
55-64	105468	34437	8043	120020	29419	91568	45715	14507	2316	38080	9937	50117
65-74	75798	48758	5753	88162	14215	75322	46215	32617	2124	21288	7354	49378
75-84	60405	90627	3988	68400	6488	78378	45617	92585	2196	12353	5978	73642
85+	22843	97229	1542	24486	1829	56510	17661	166219	1135	4432	2565	91787

Mortality data: National monthly Age Standardised Death Rates (ASDRs)



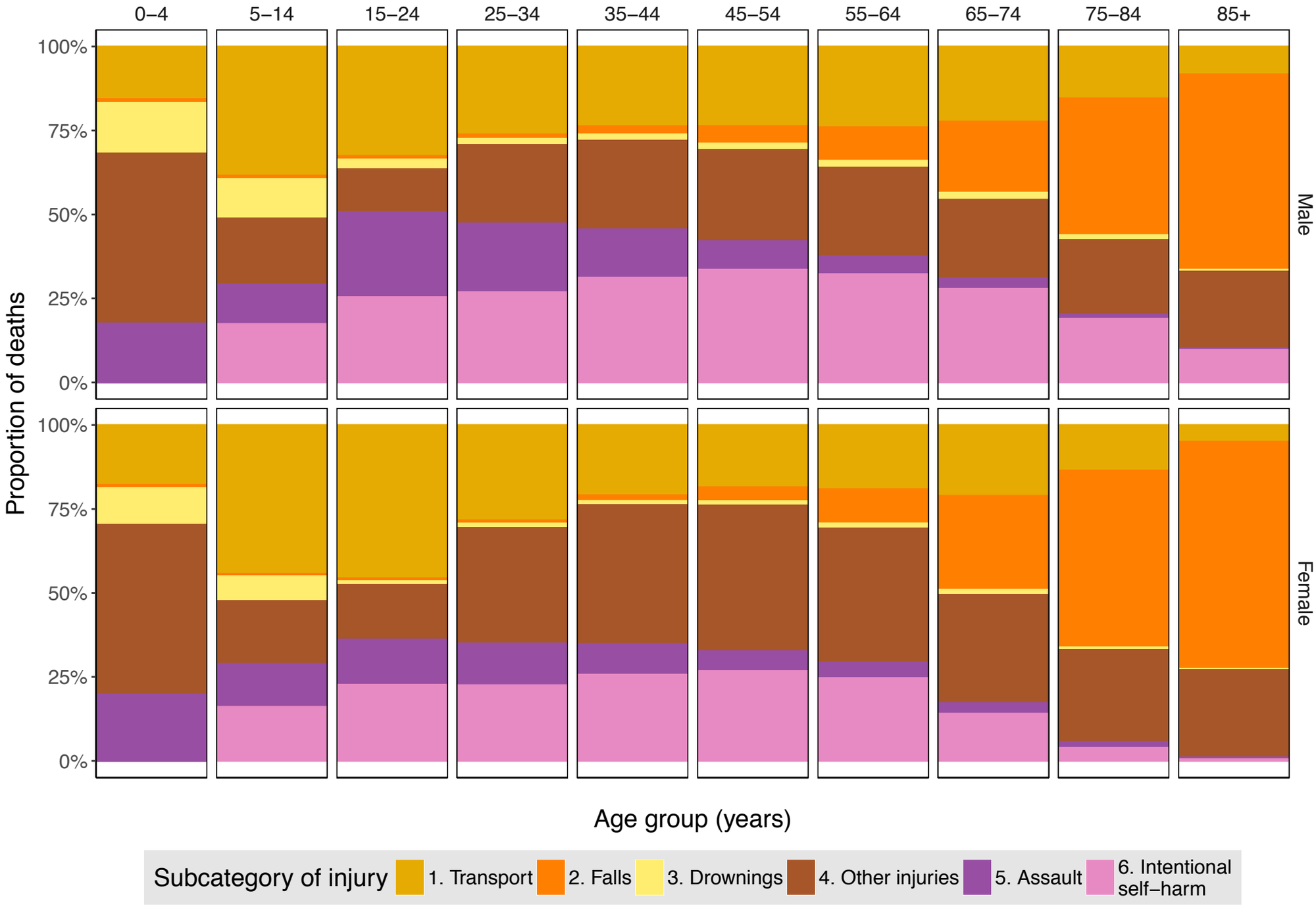
Global Environmental Health

Mortality data: National monthly Age Standardised Death Rates (ASDRs)



Global Environmental Health

Mortality data: Proportion of broad causes of death by age-sex group



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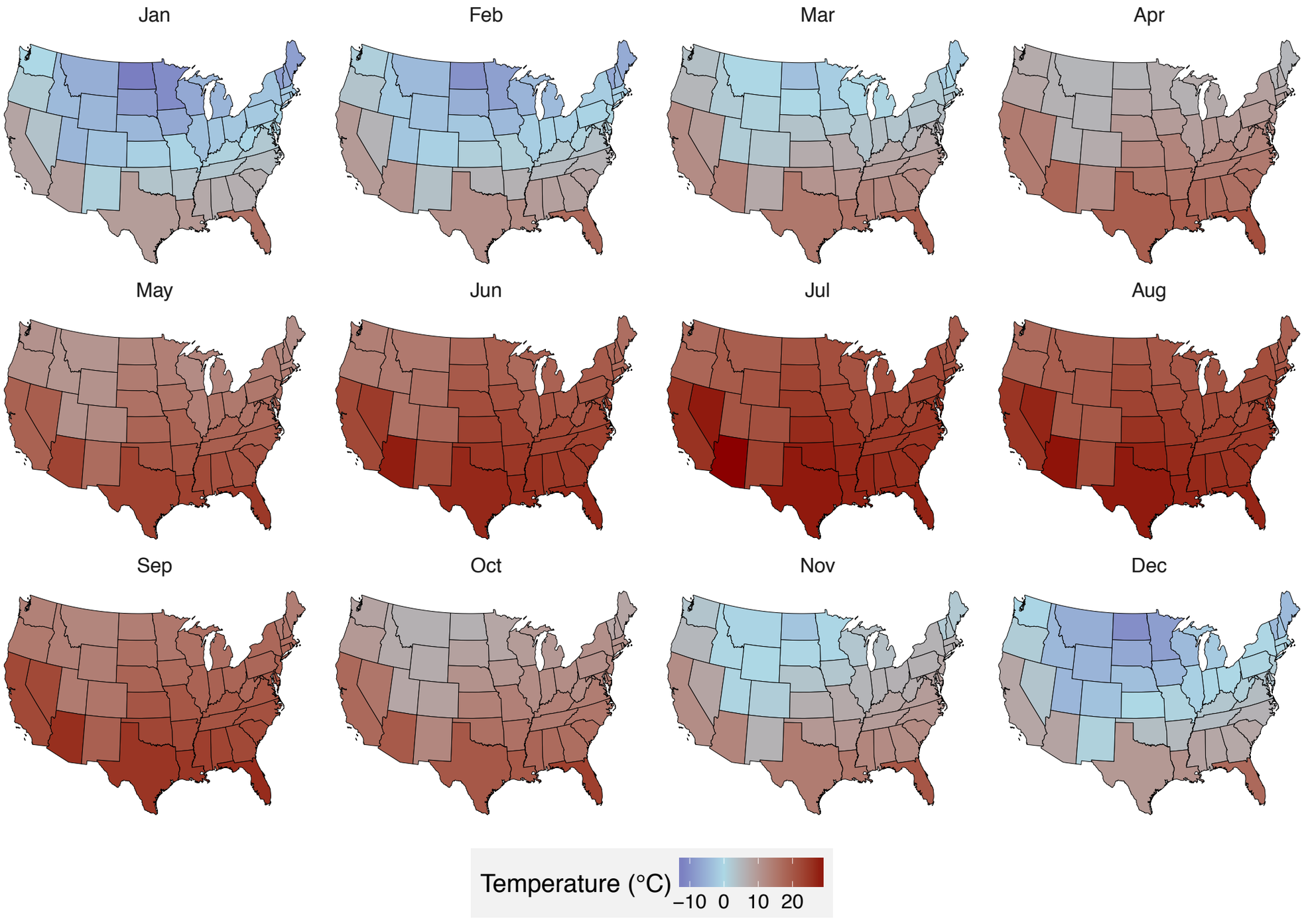
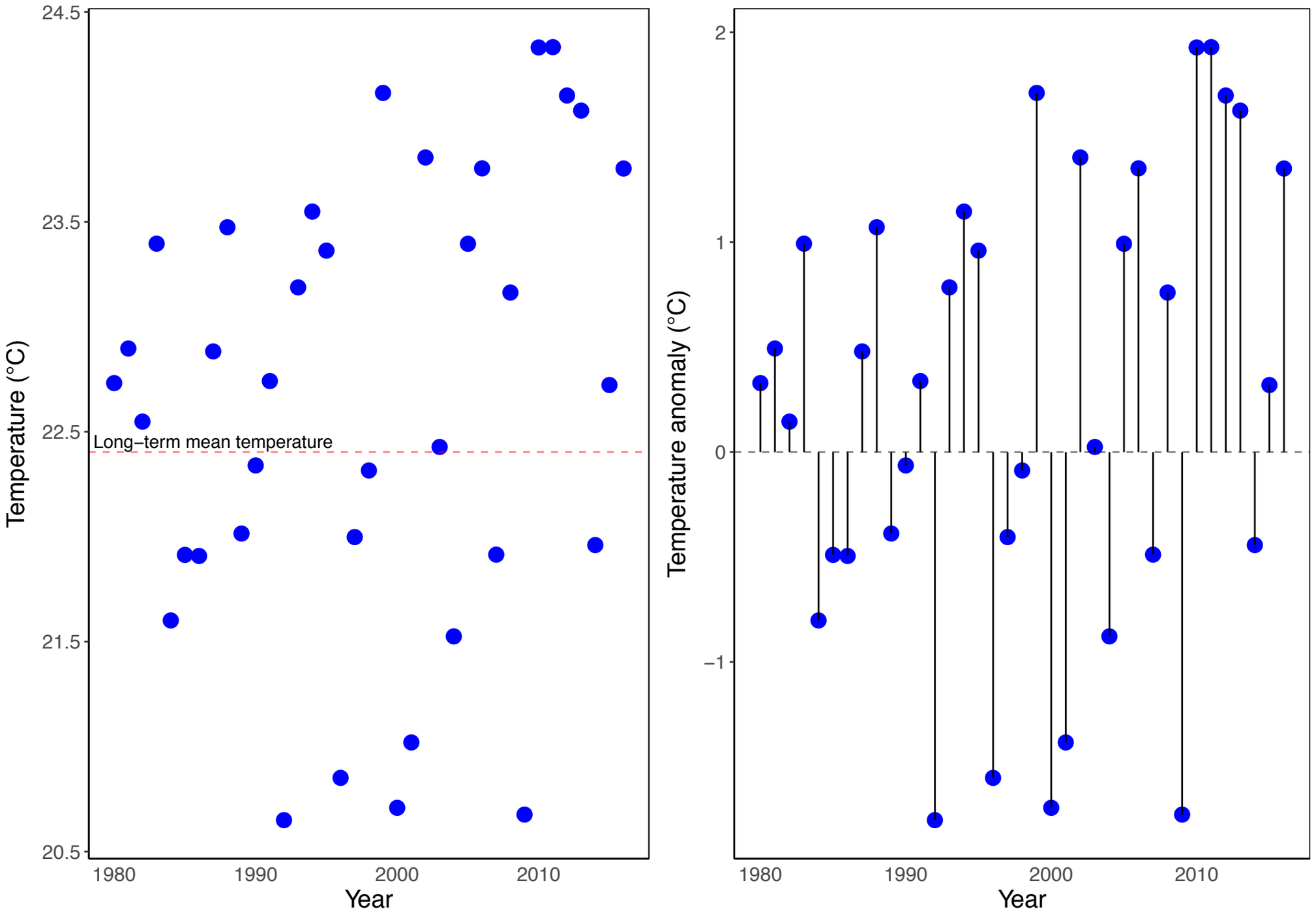
Temperature data: 30-year normals (1980-2009)



Global Environmental Health

Temperature data: Schematic of change from long-term average



Global Environmental Health

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- $\text{Death rates}_{[m,s,t]}$ modelled via log-link function:

$$\begin{aligned}\log(\text{Death rates}_{[m,s,t]}) =& (\alpha_0 + \beta_0.t) \\ &+(\alpha_m + \beta_m.t) \\ &+(\alpha_s + \beta_s.t) \\ &+\gamma_m.\text{Anomaly}_{m,s,t} \\ &+\xi_{m,s} \\ &+\pi_t+ \\ &+\epsilon_{m,s,t}\end{aligned}$$

where:
α = intercepts, β = time-slopes, γ = temperature effects,
ξ = state-month interaction, π = random walk over time,
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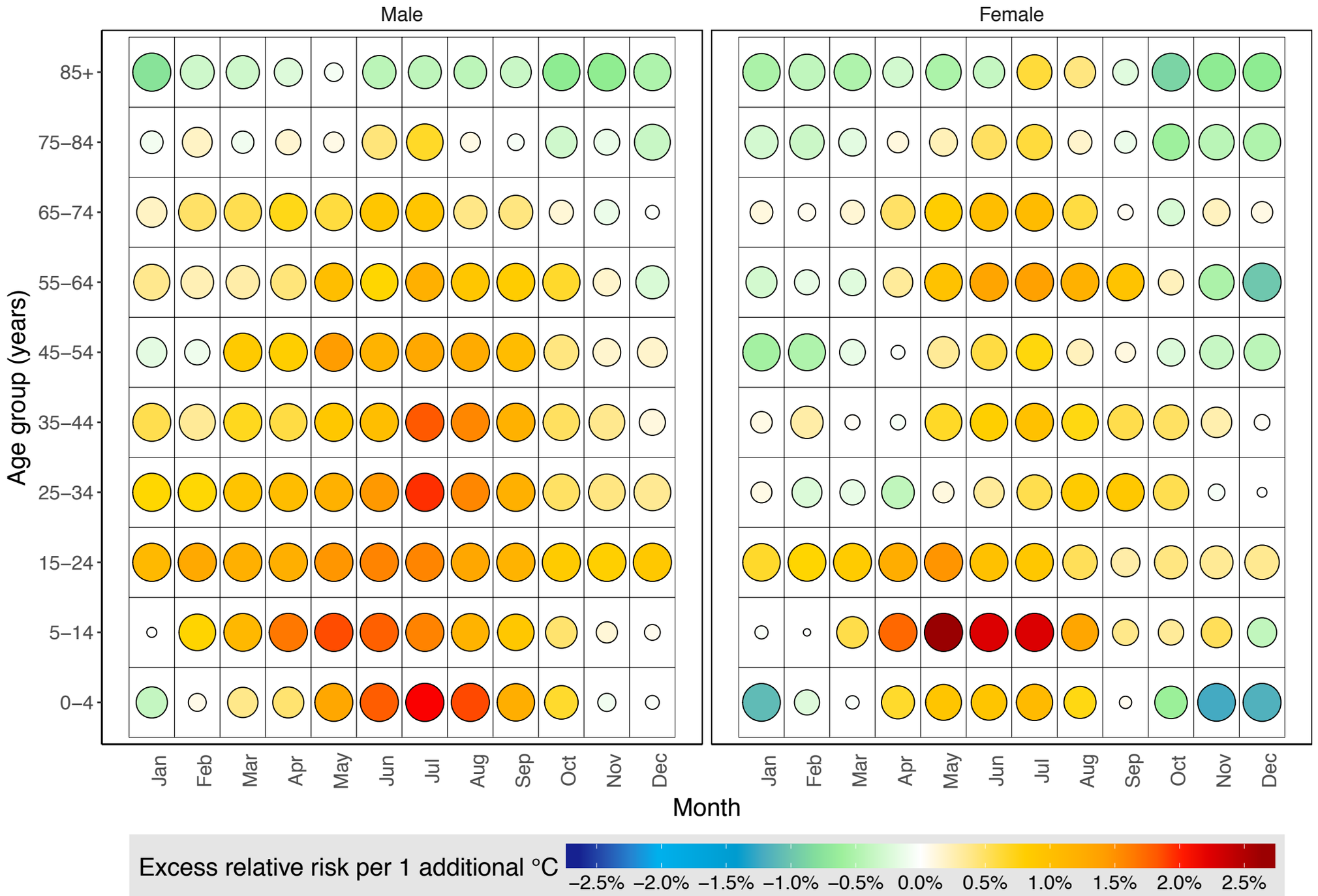
Anomaly = Temperature anomaly term (see Fig. 3)

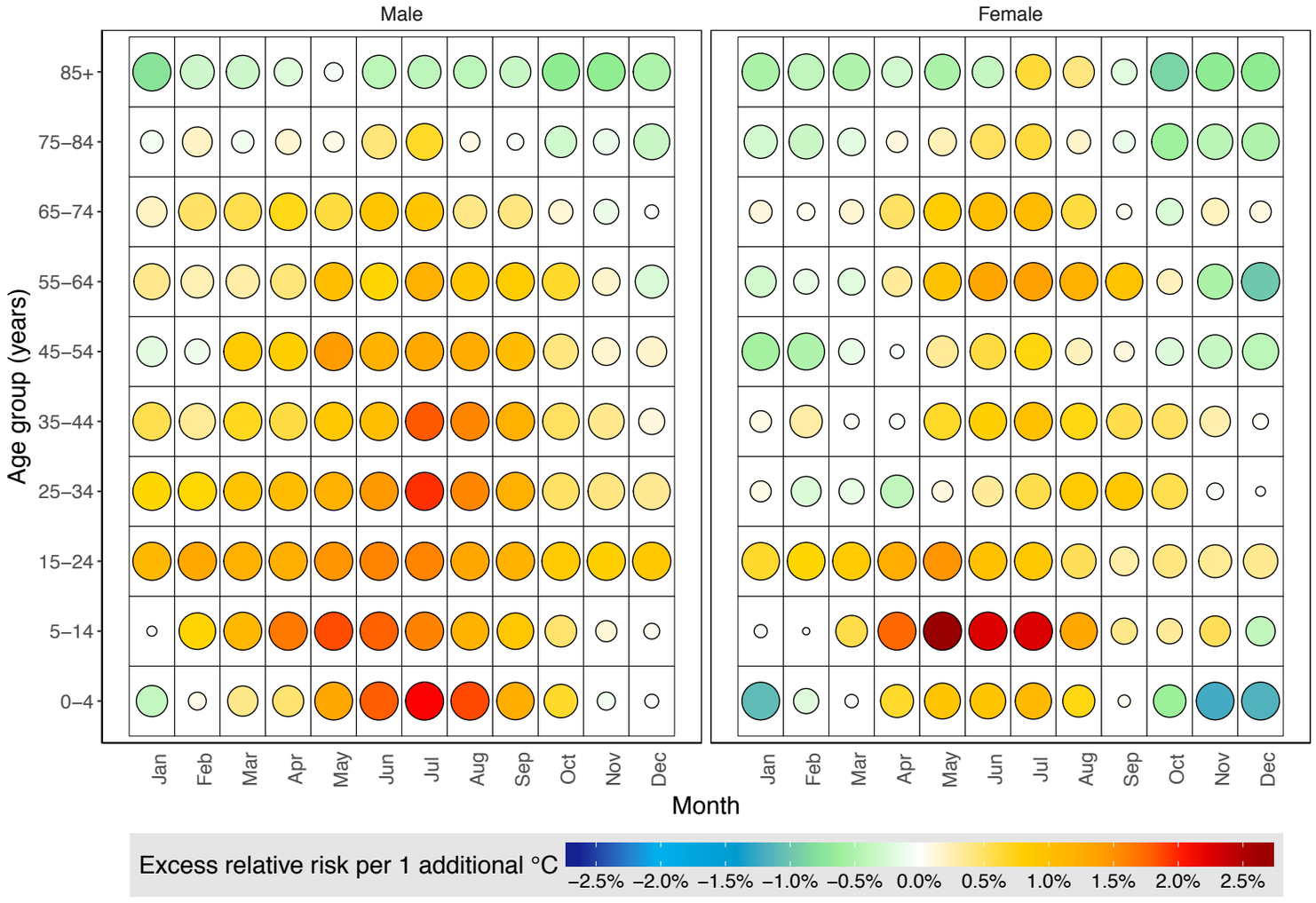
Global Environmental Health

Risk figures

Injury excess risk (2-metre temperature)



Injury excess risk (2-metre temperature)



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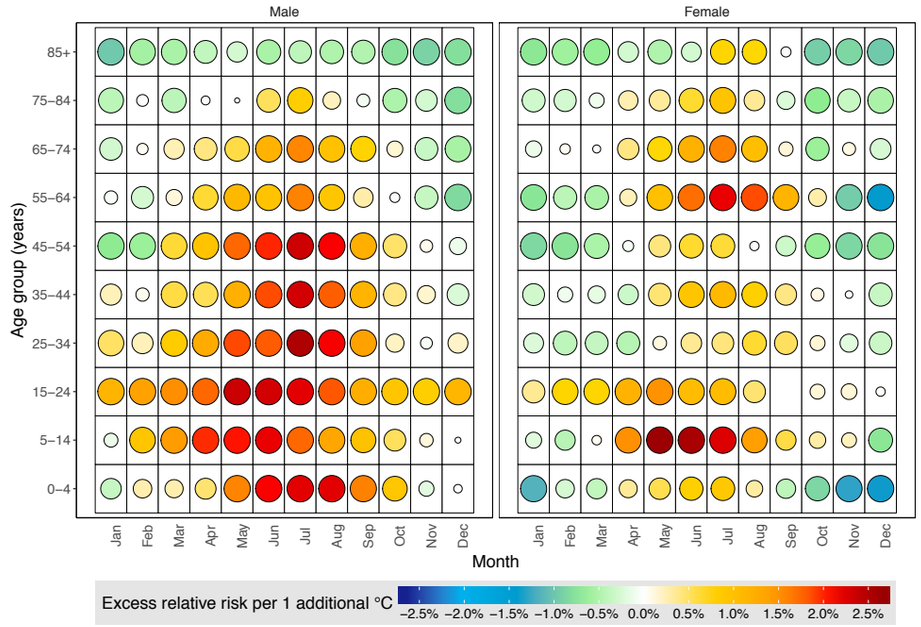

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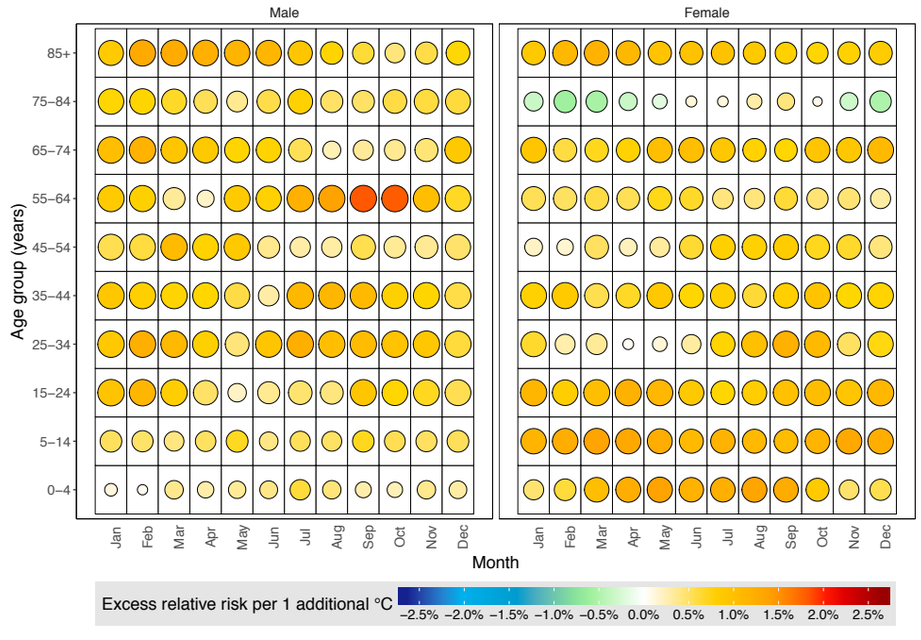
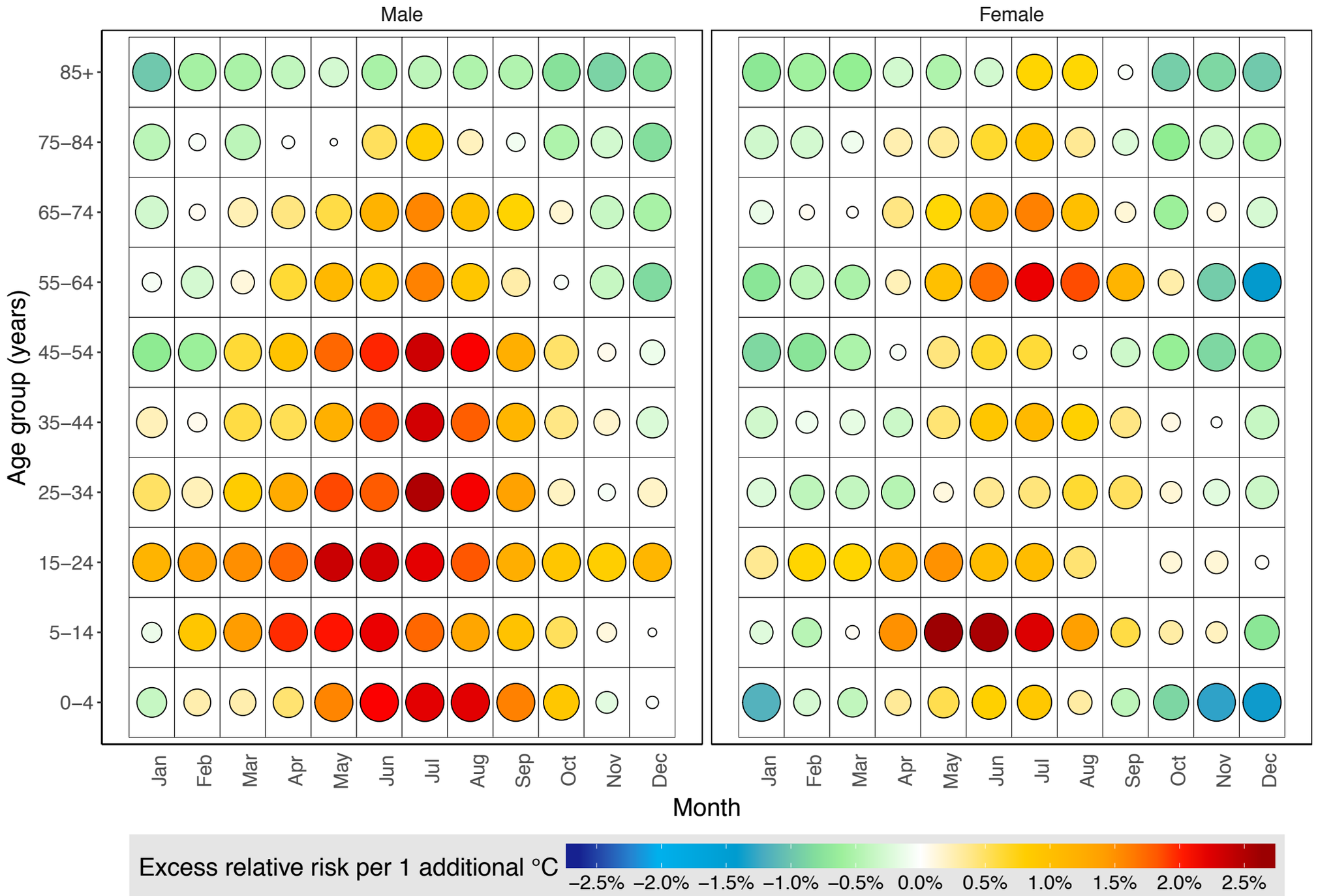
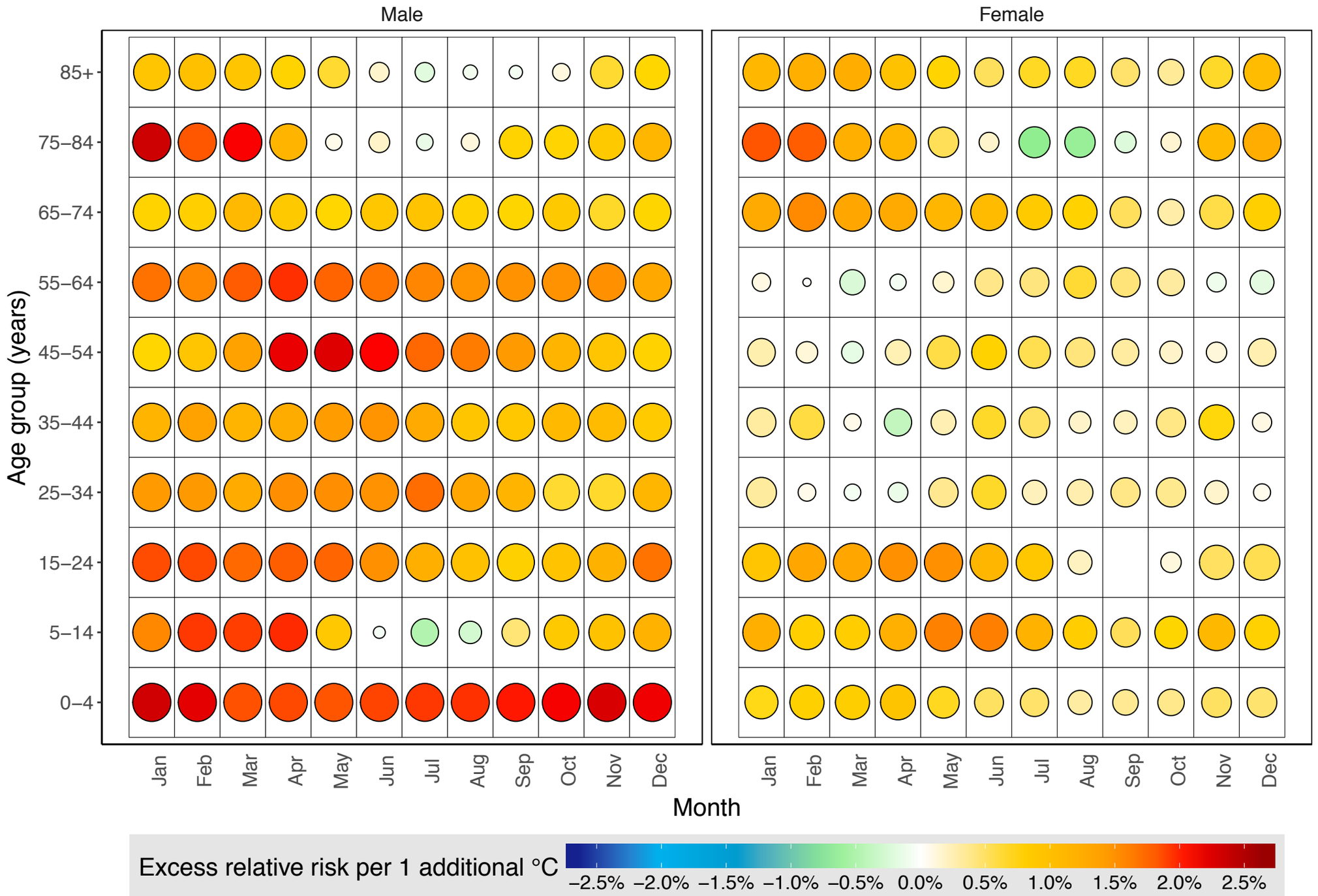


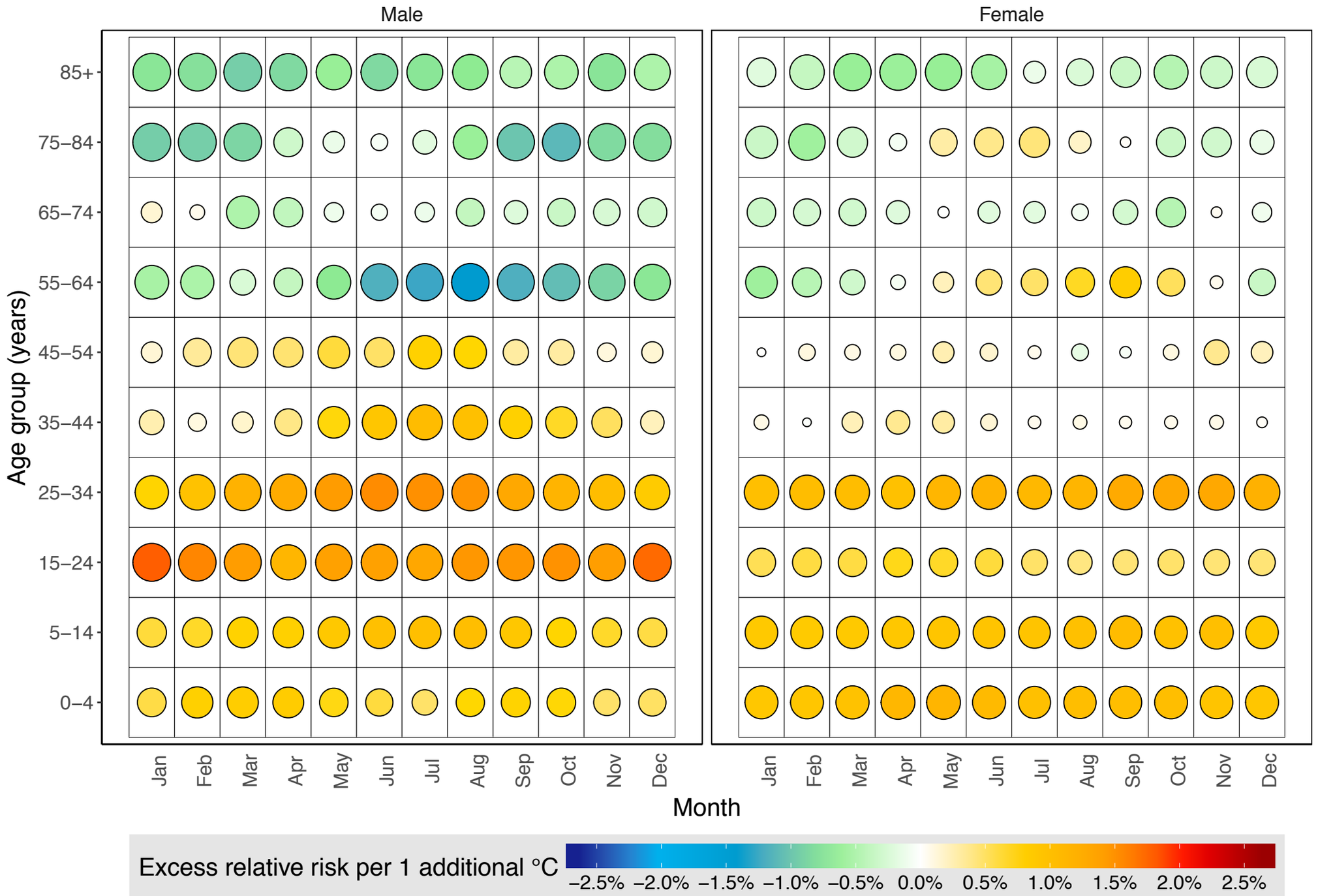
Unintentional injuries excess risk (2-metre temperature)



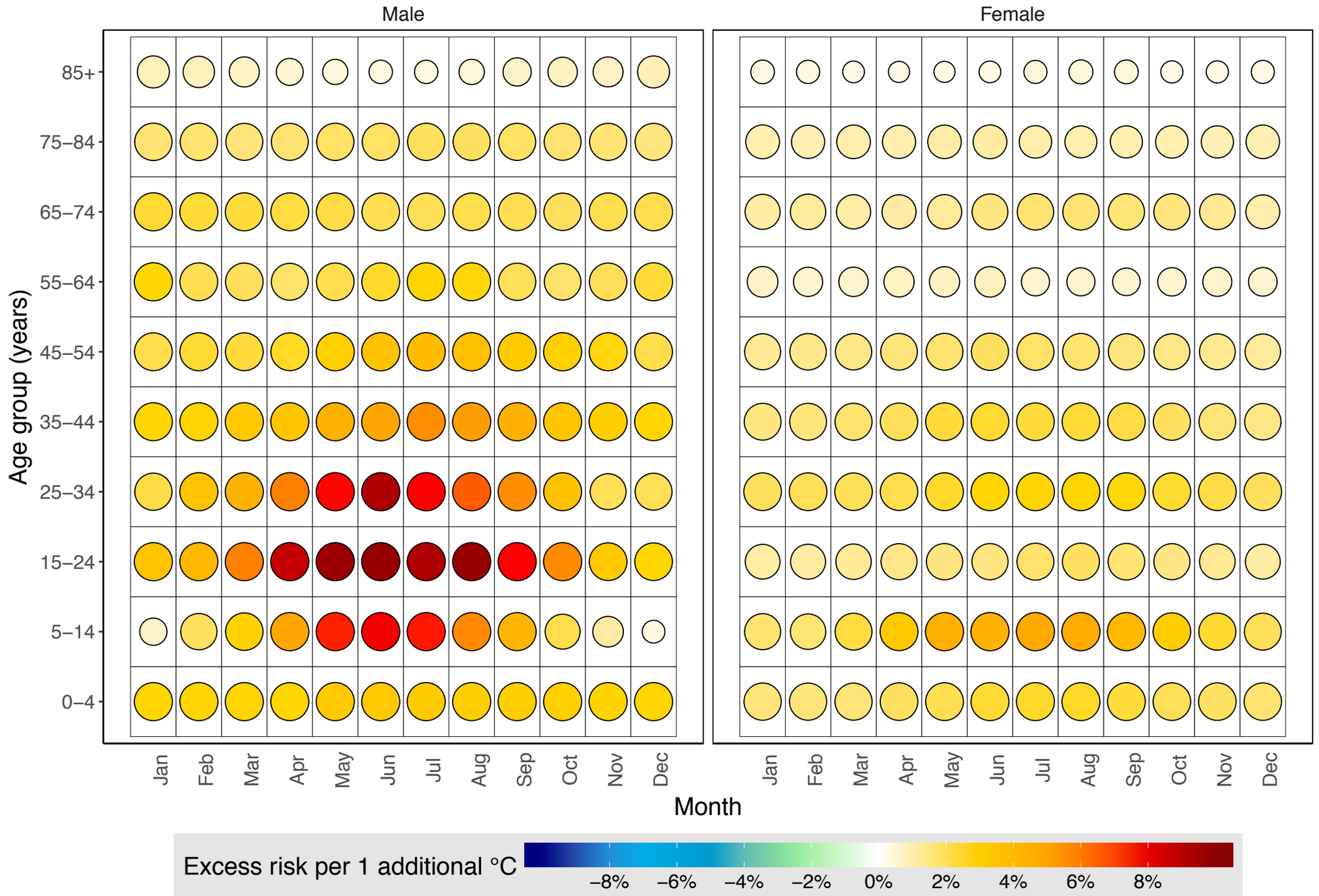
Transport (2-metre temperature)



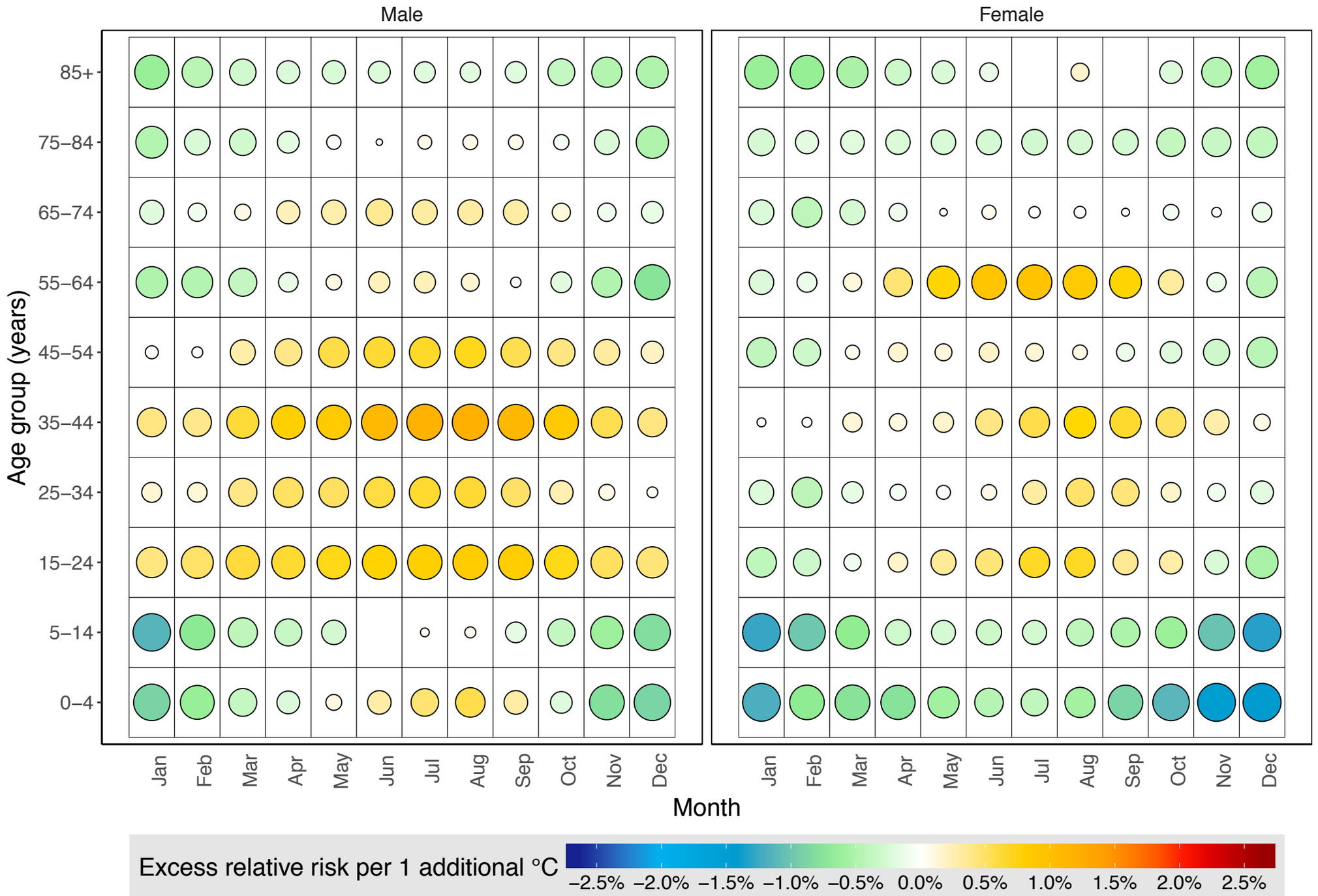
Falls (2-metre temperature)



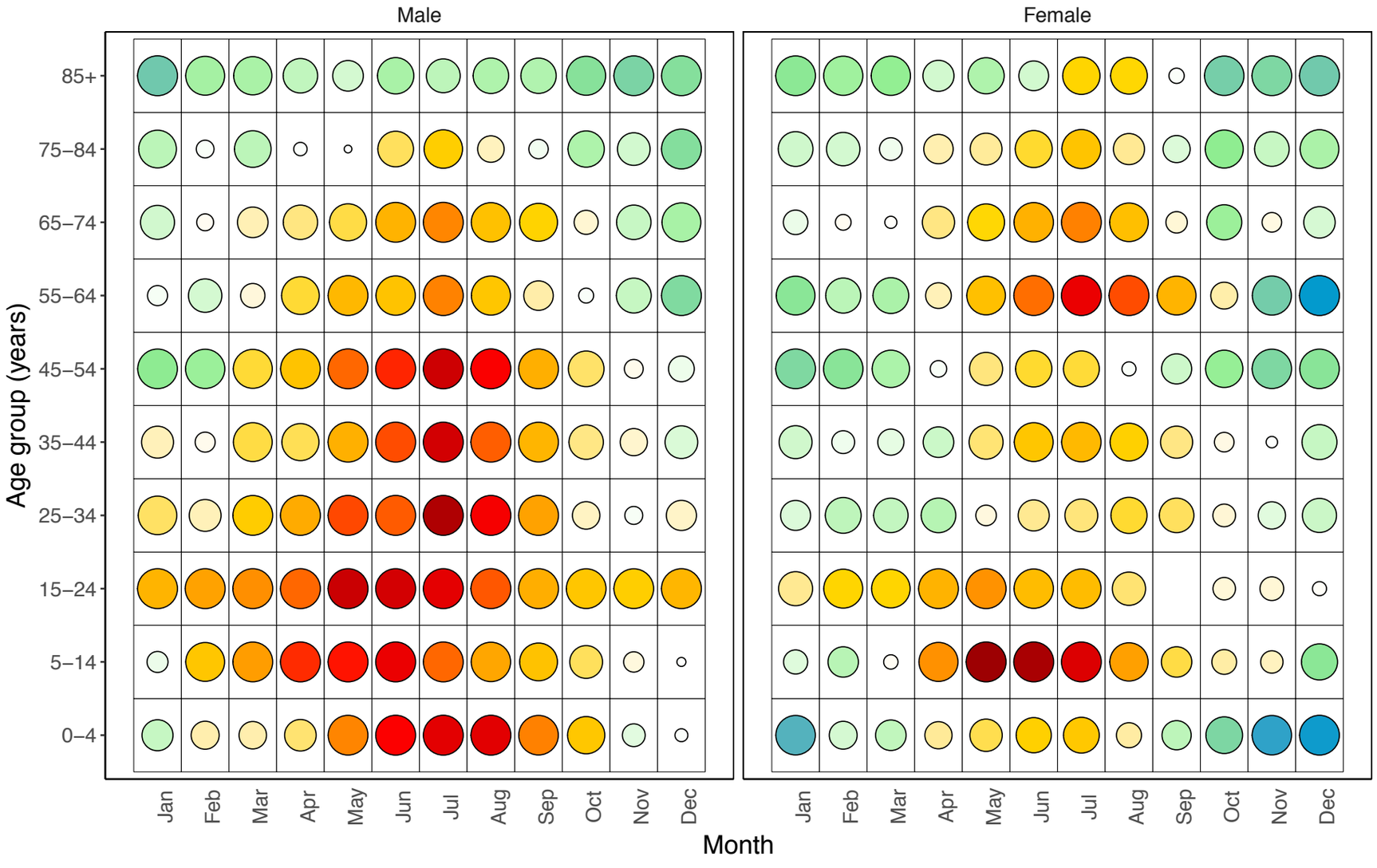
Drownings (2-metre temperature)

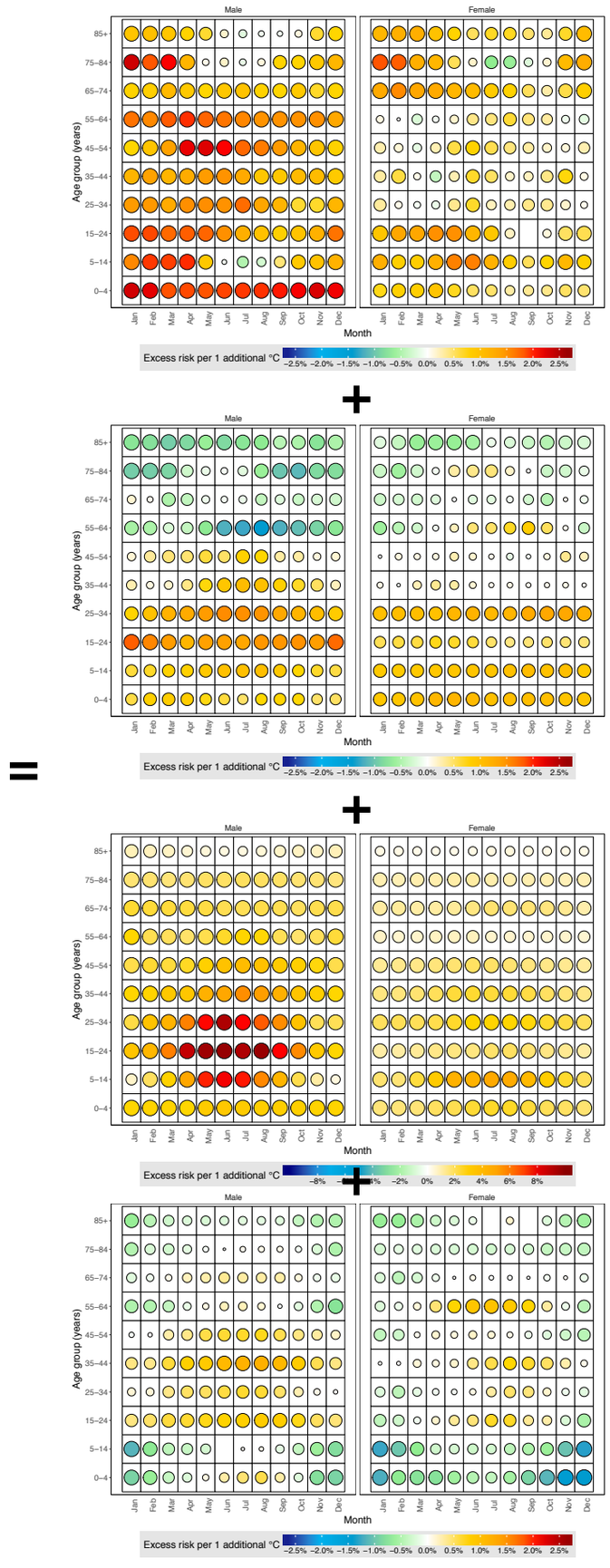


Other unintentional injuries (2-metre temperature)

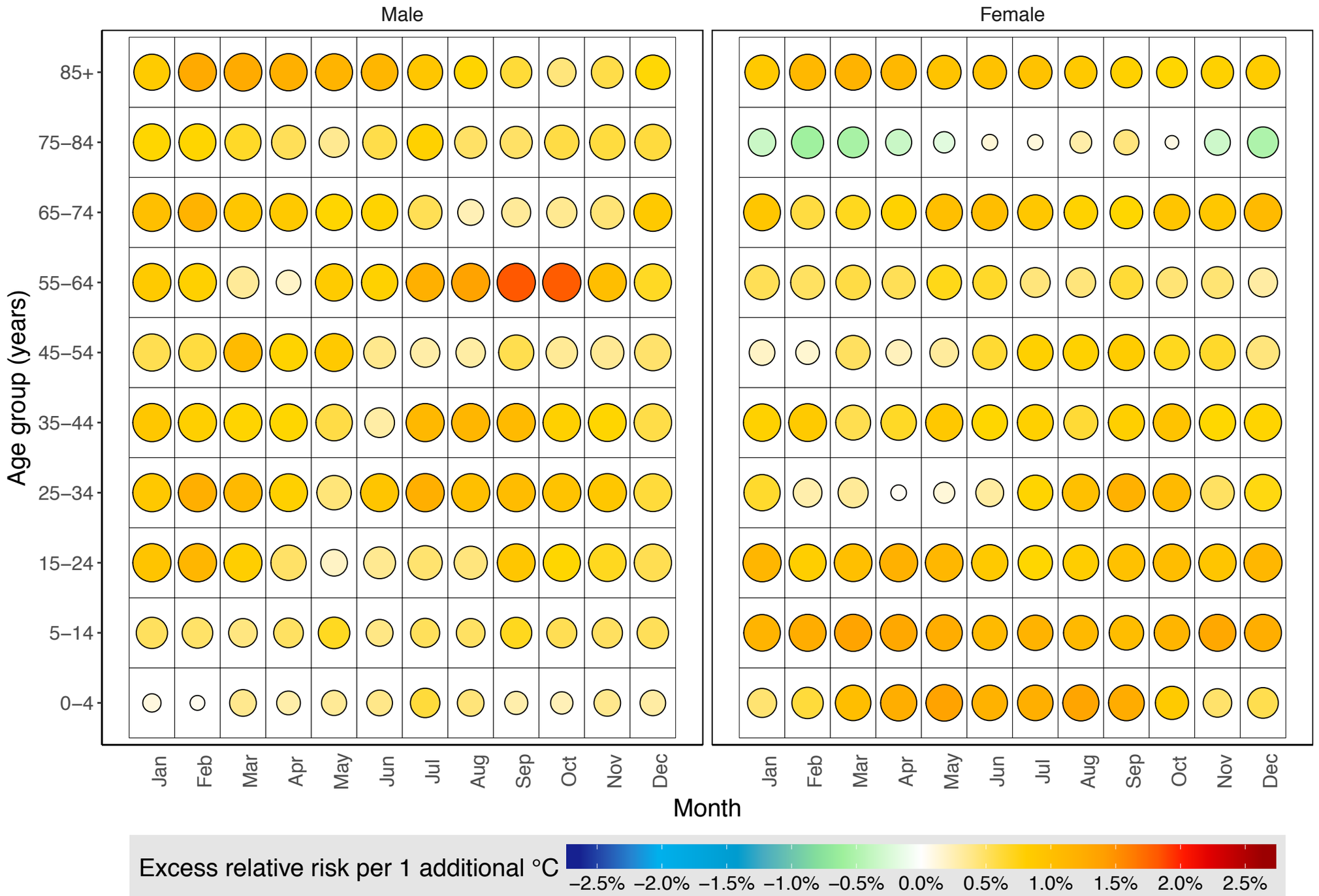


Unintentional injury excess risk (2-metre temperature)

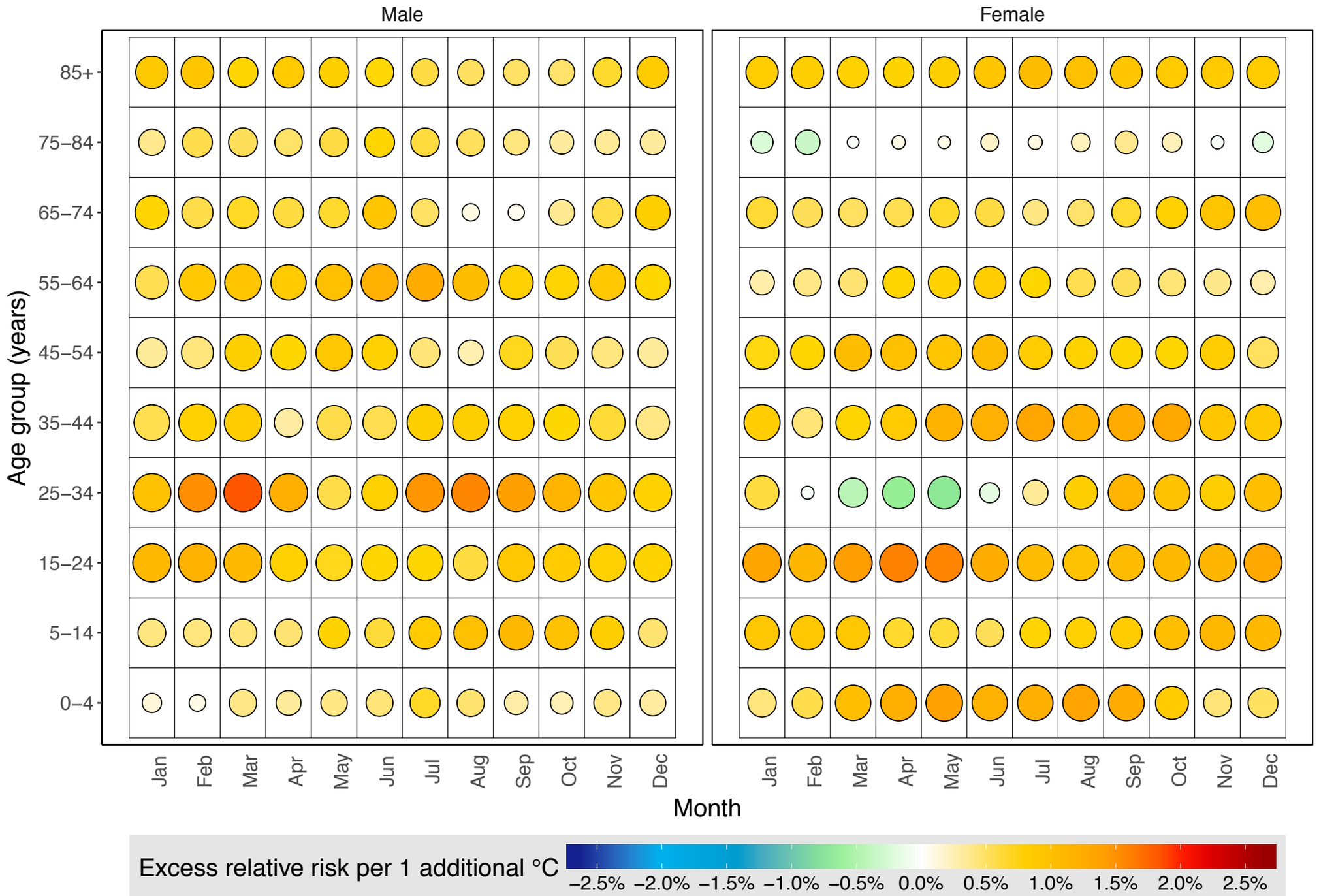




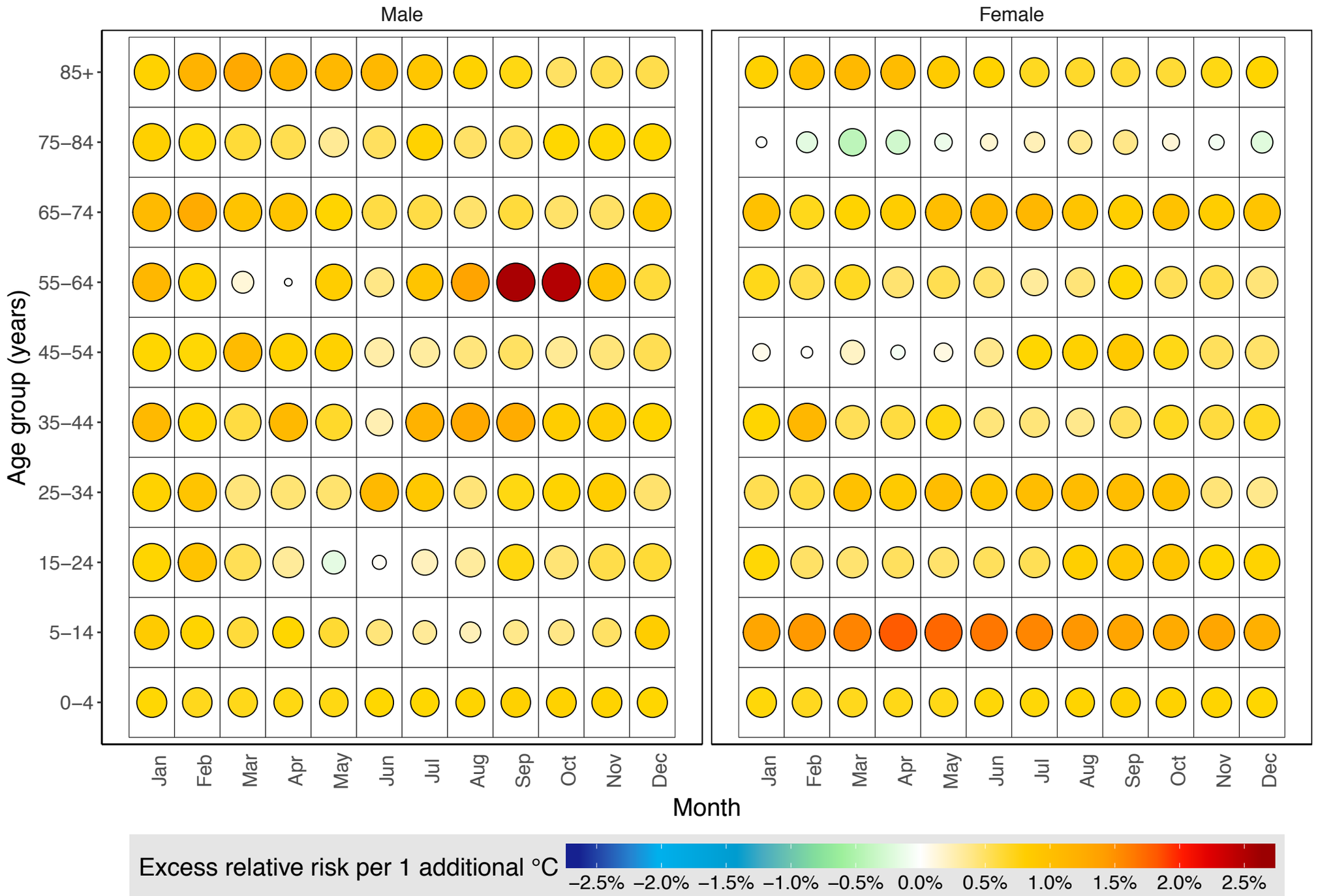
Intentional injury excess risk (2-metre temperature)



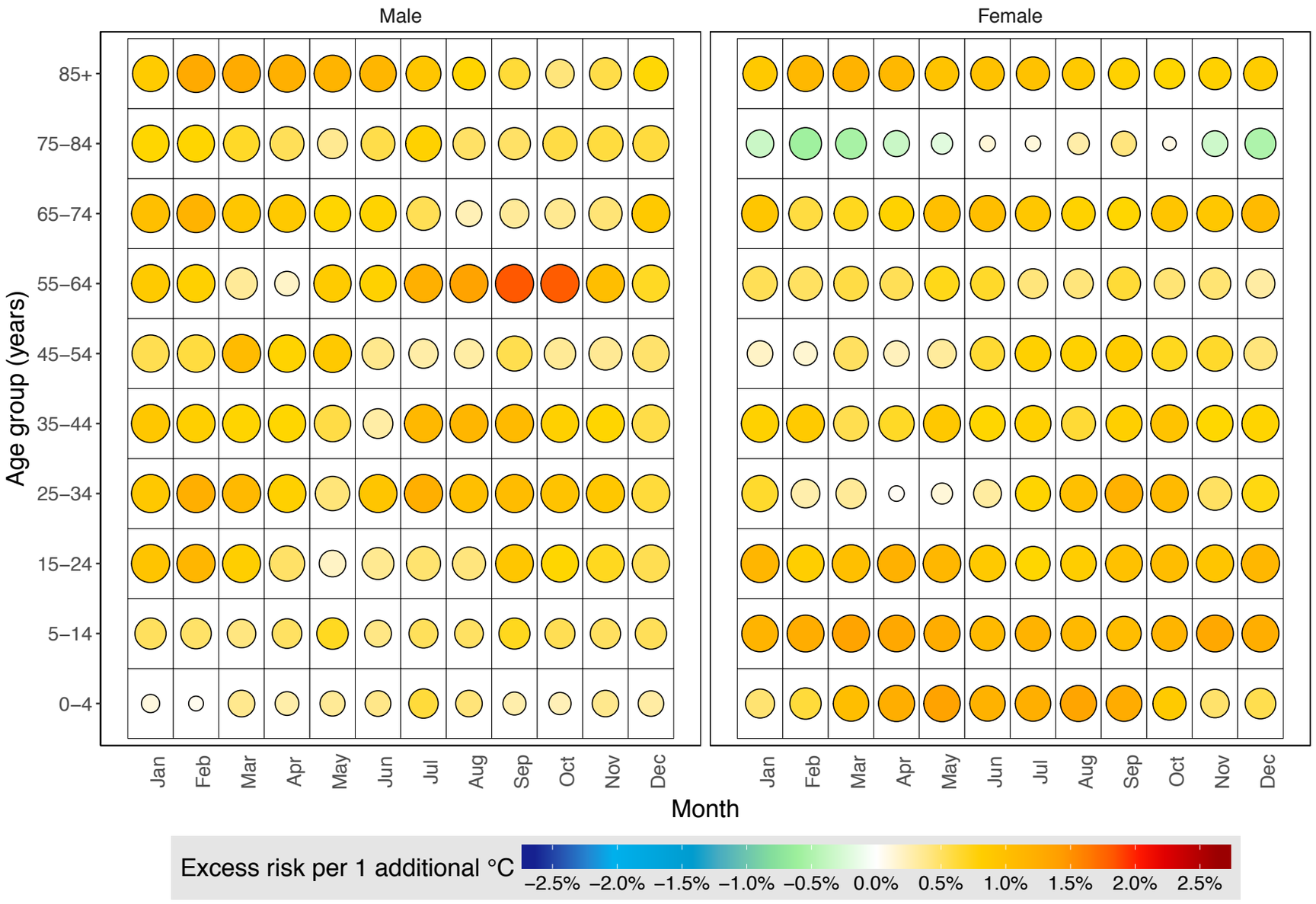
Assault injury excess risk (2-metre temperature)

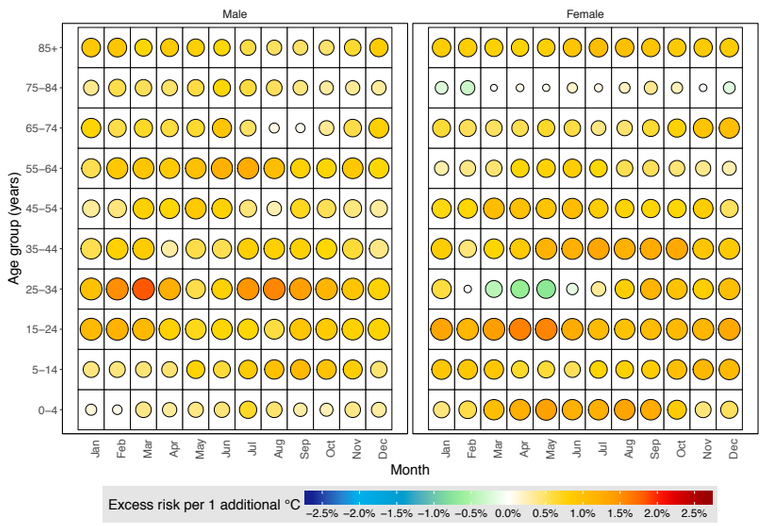


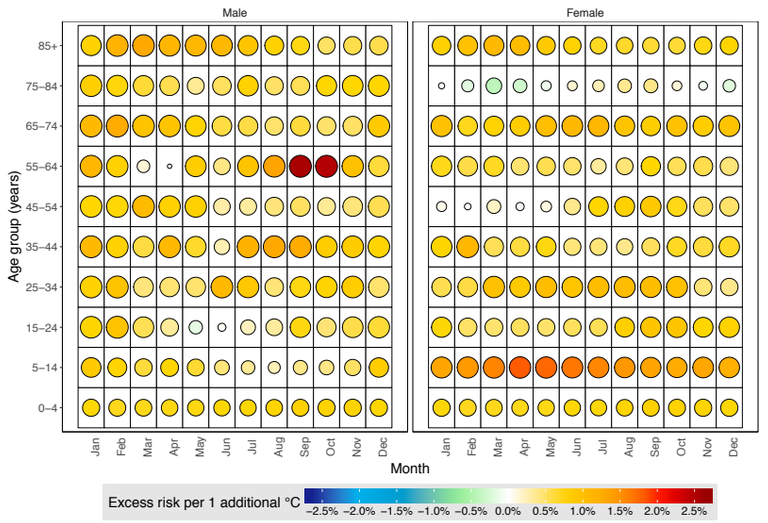
Intentional self-harm injury excess risk (2-metre temperature)



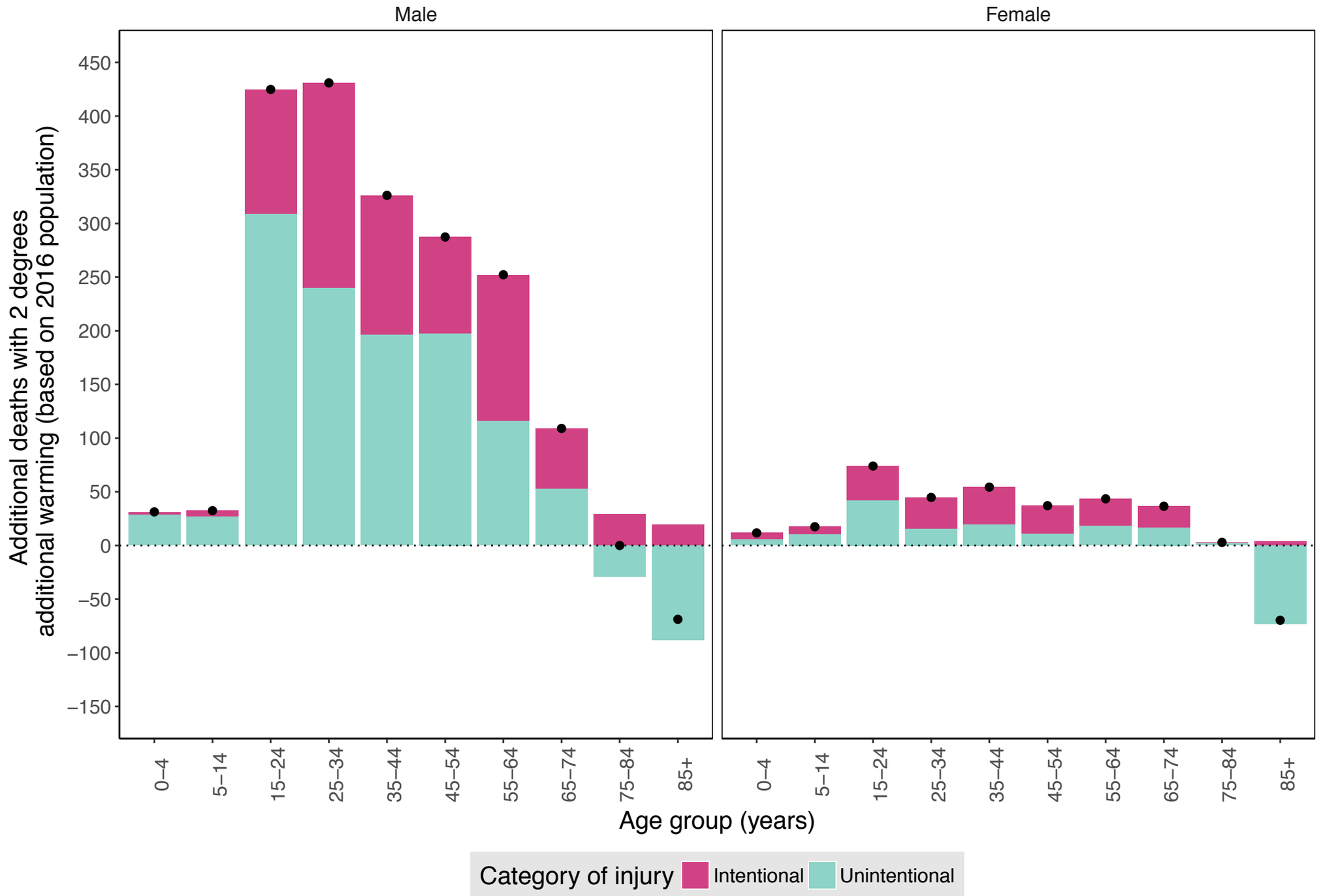
Unintentional injury excess risk (2-metre temperature)



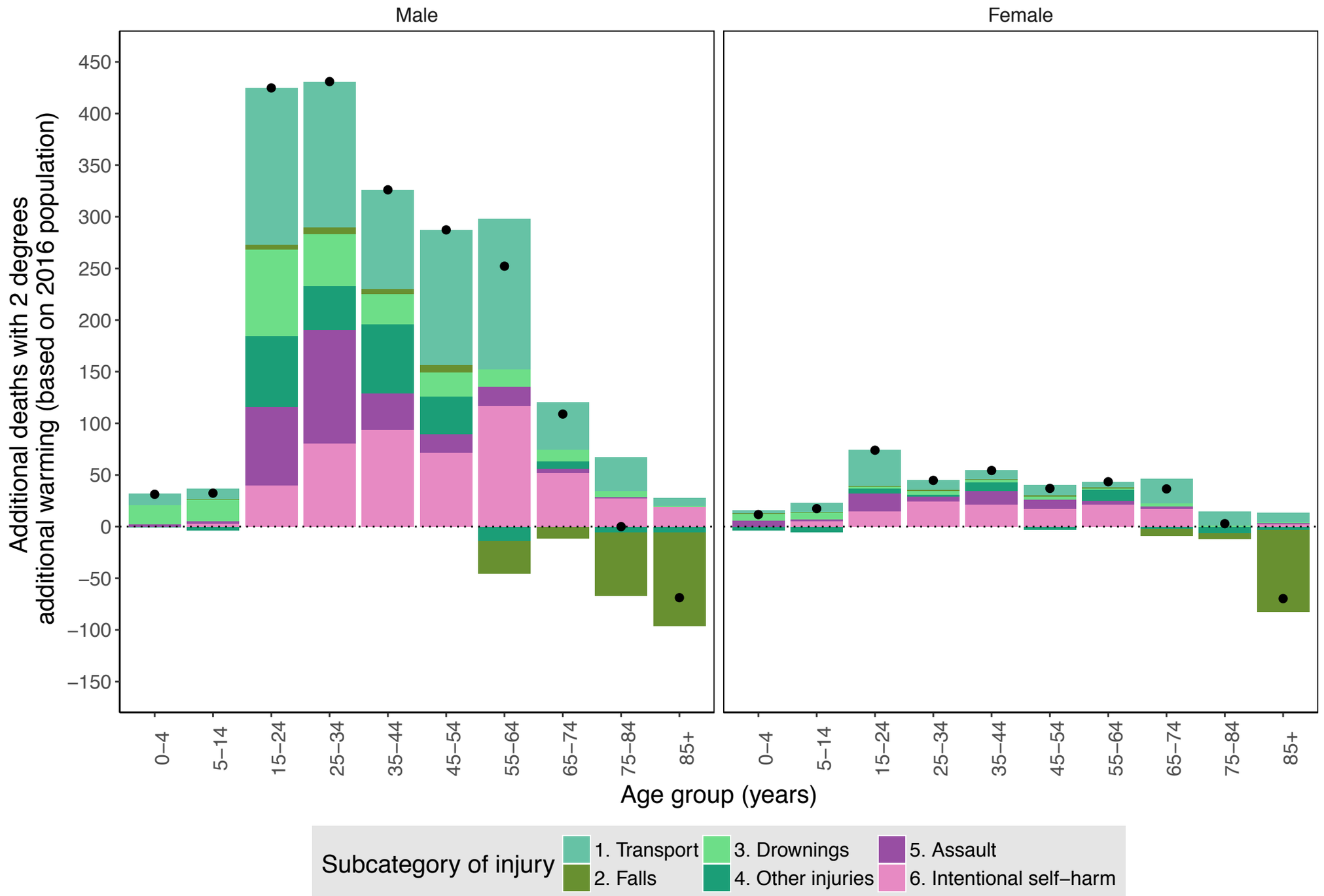




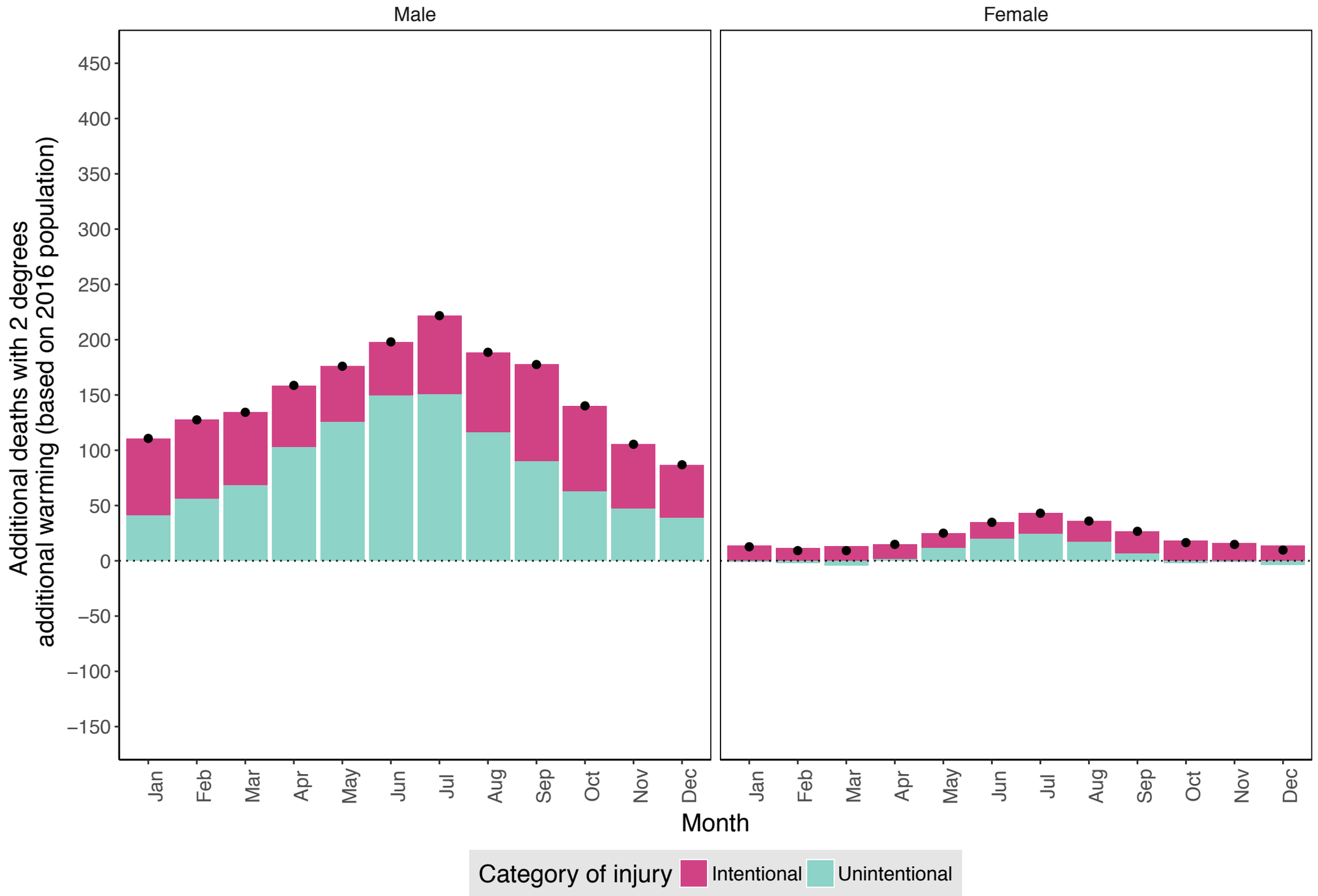
All injuries: Additional deaths with 2deg by age (total=2,078)



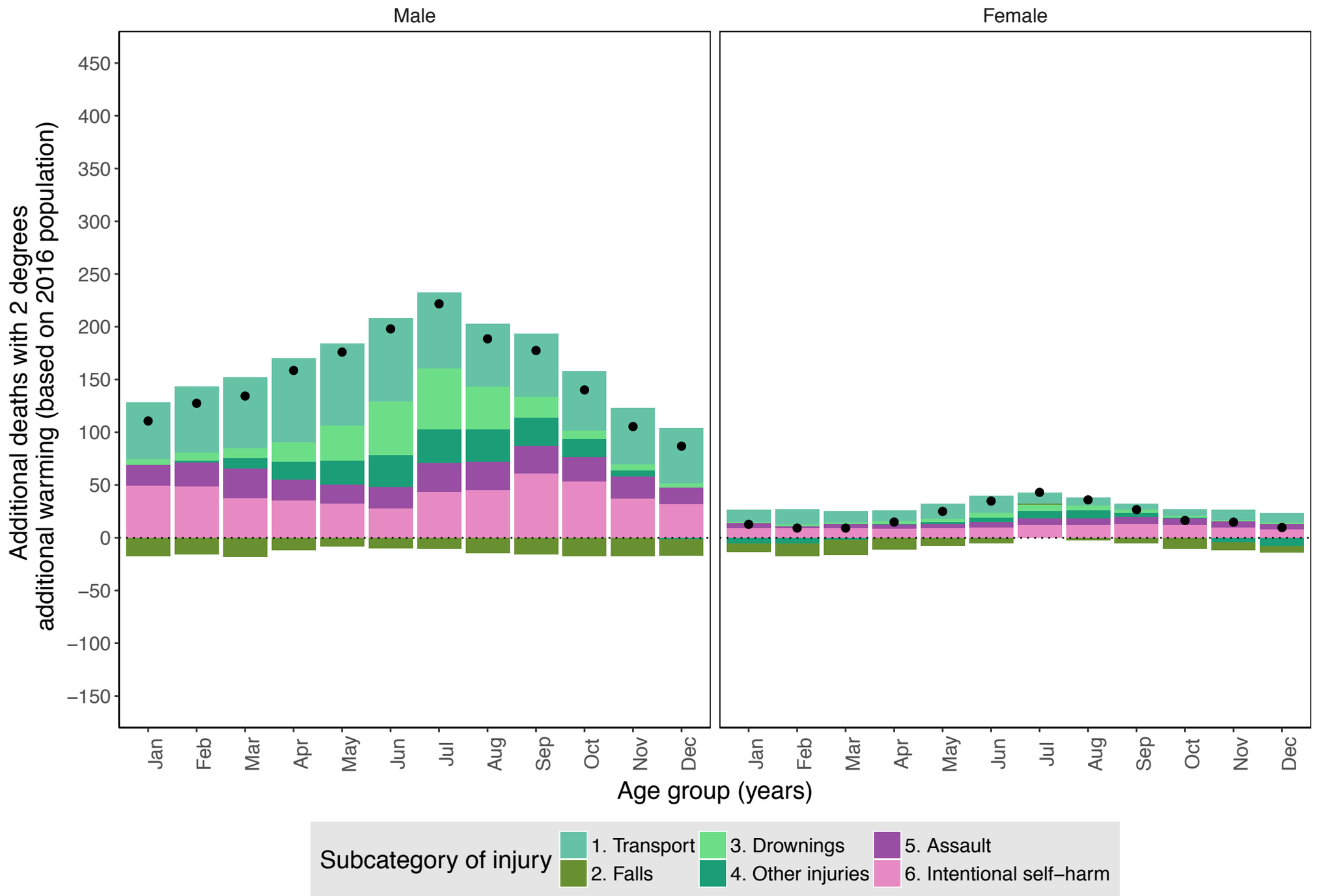
All injuries: Additional deaths with 2deg by age (total=2,078)



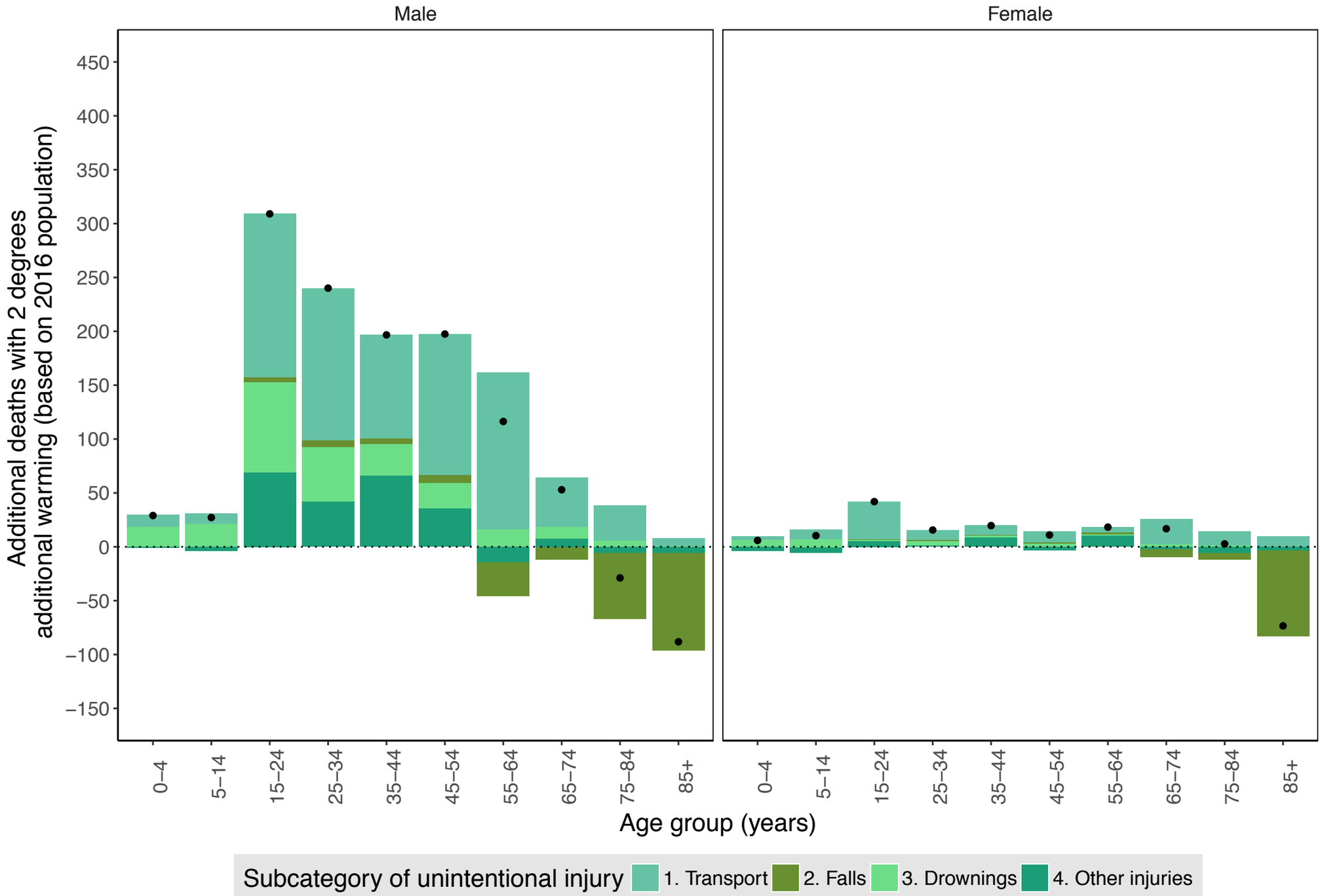
All injuries: Additional deaths with 2deg by month (total=2,078)



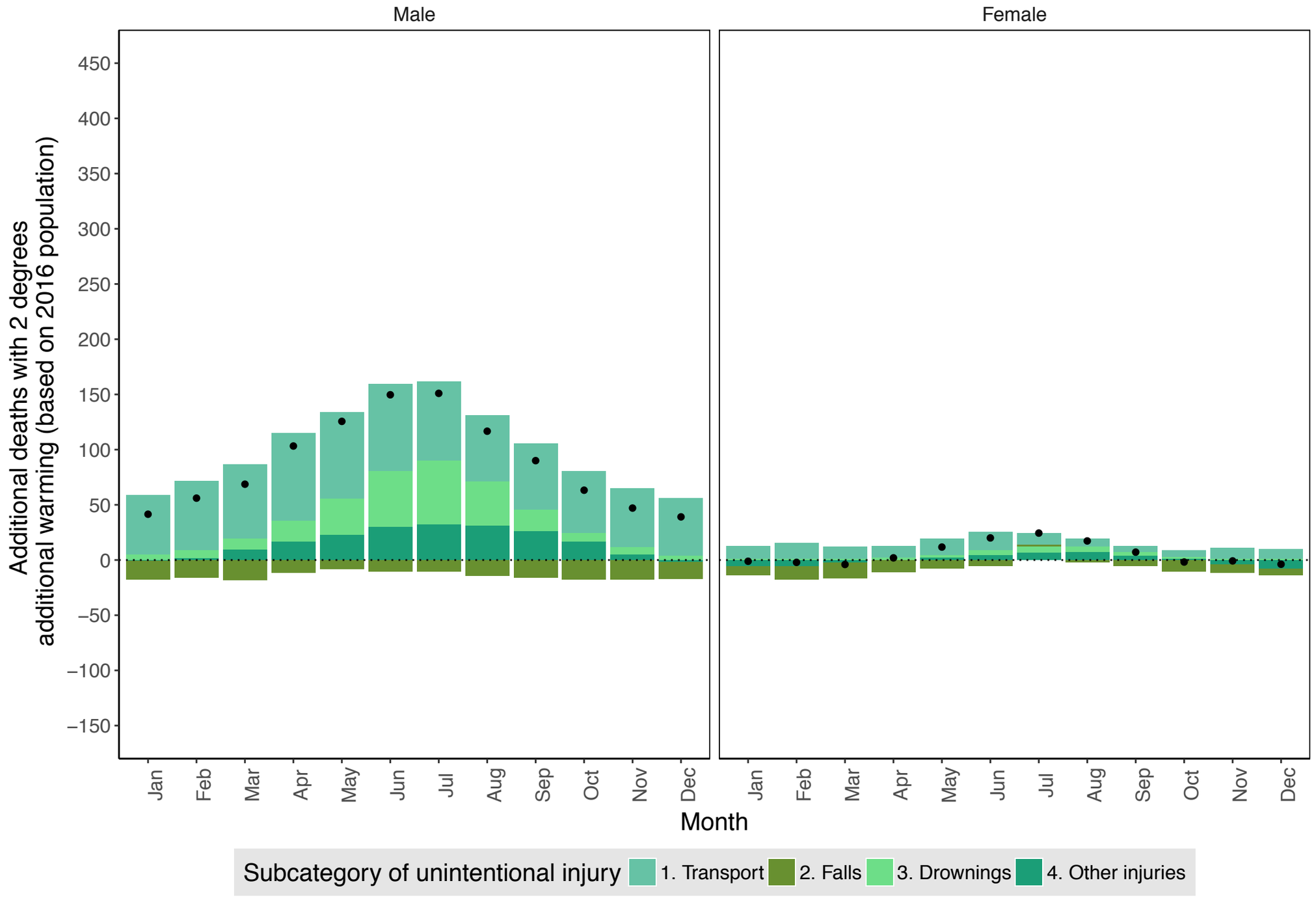
All injuries: Additional deaths with 2deg by month (total=2,078)



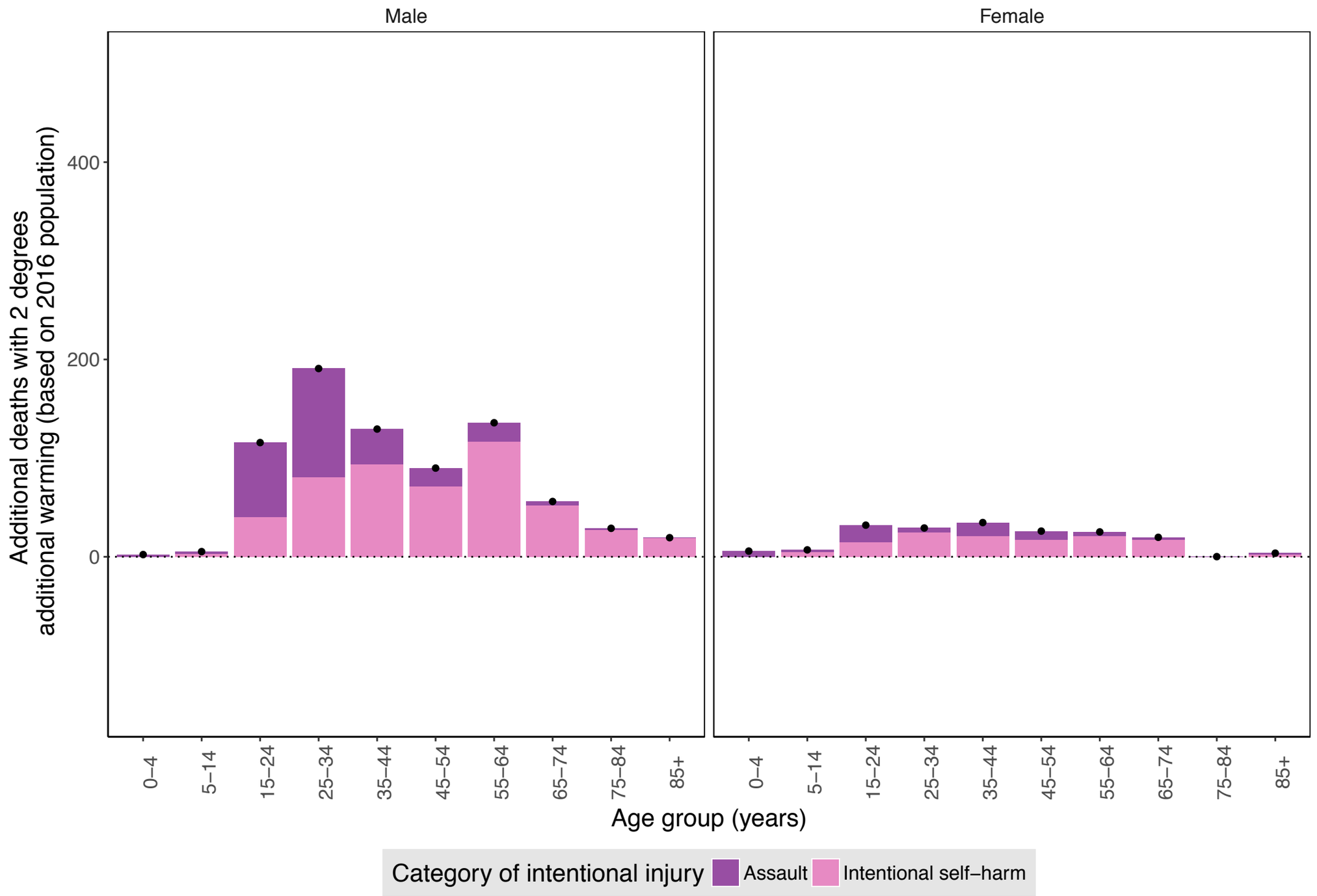
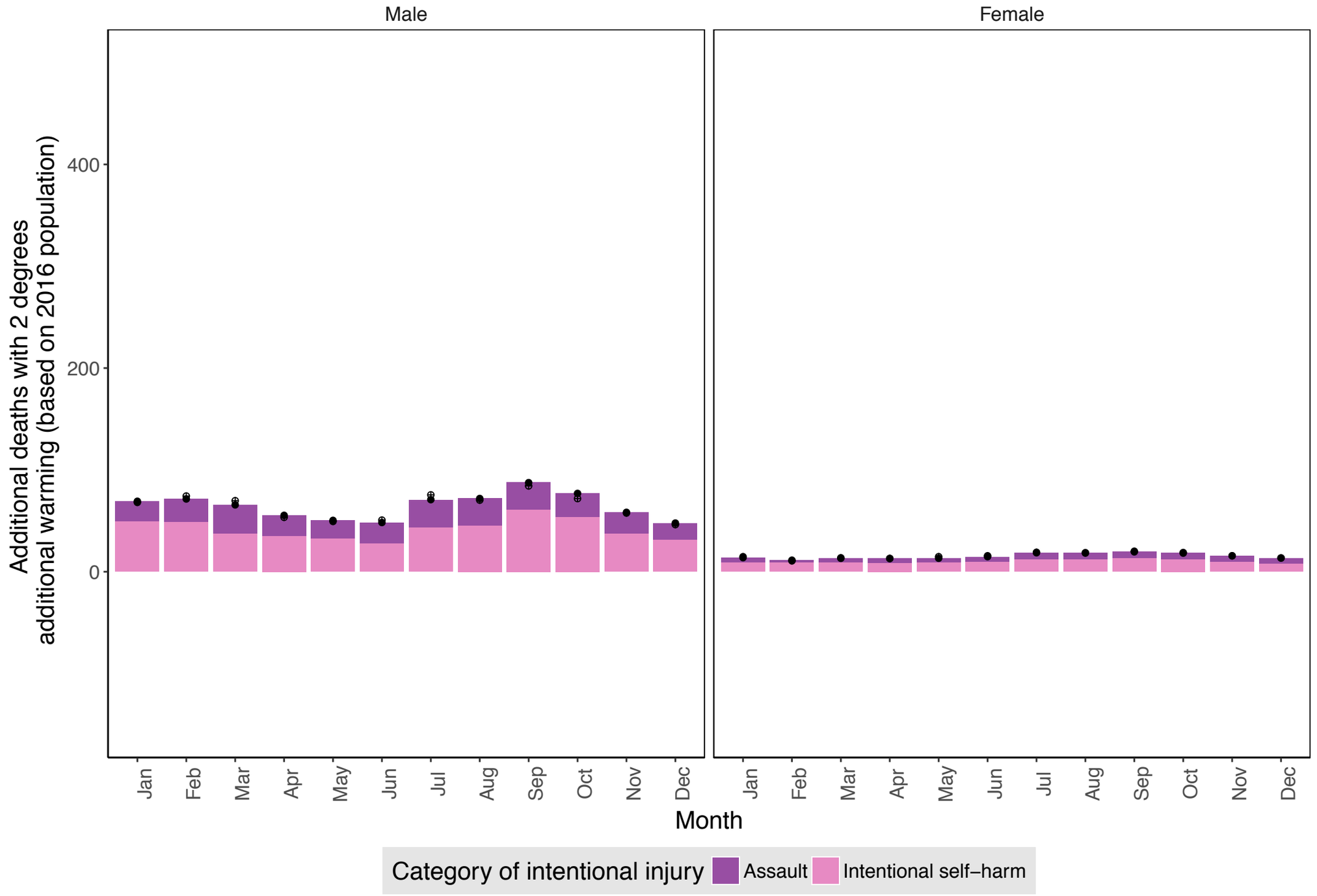
Unintentional injuries: Additional deaths with 2deg by age (total=1,121)



Unintentional injuries: Additional deaths with 2deg by month (total=1,121)



Intentional injuries: Additional deaths with 2deg by age (total=957)



Intentional injuries: Additional deaths with 2deg by month (total=957)