

**Supplementary Table S1.** Descriptions of the baseline temperature conditions and semen samples from the study regions during the five warmest months during 2014–2020

Region	Time period	Total Observations	Daily mean temperature (Median [IQR])	95th percentile of <i>Tmin</i>	90th percentile of <i>Tmin</i>	97.5th percentile of <i>Tmin</i>
Guangdong	2016–2018	6319	26.22 (24.84, 27.31)	26.04	25.45	26.60
Hubei	2014–2018	504	23.78 (20.93, 26.49)	26.55	25.35	27.30
Henan	2014–2018	1588	24.07 (21.21, 26.77)	25.97	25.17	26.80
Sichuan	2014–2019	181	15.40 (8.97, 21.19)	22.90	21.33	24.07
Shanxi	2014–2019	176	20.85 (17.5, 24.01)	23.43	21.79	24.65
Zhejiang	2014–2020	4733	24.48 (22.02, 26.97)	25.99	25.17	26.68

**Note.** IQR, interquartile range; *Tmin*, daily minimum temperature in region's historical period.

**Supplementary Table S2.** Characteristics and distribution of semen parameters in uninvolved study subjects

Characteristics	<i>n</i> (%)	Sperm quality ( $\bar{x} \pm s$ )							
		Sperm concentration, $\times 10^6/\text{mL}$	<i>P</i> -value <sup>a</sup>	Sperm count, $\times 10^6$	<i>P</i> -value <sup>a</sup>	Progressive motility, %	<i>P</i> -value <sup>a</sup>	Total motility, %	<i>P</i> -value <sup>a</sup>
All Observations	65,451 (100.0)	72.46 ± 38.24		253.40 ± 158.85		50.71 ± 14.25		55.41 ± 13.24	
Age, years			< 0.001		0.041		< 0.001		< 0.001
< 30	47,185 (72.1)	71.18 ± 37.11		253.51 ± 156.93		50.97 ± 13.87		55.47 ± 13.04	
30–39	16,157 (24.7)	75.01 ± 40.22		252.71 ± 163.34		50.18 ± 15.12		55.42 ± 13.72	
≥ 40	2,109 (3.2)	81.58 ± 44.80		256.32 ± 166.65		48.94 ± 15.50		53.93 ± 13.87	
Ethnicity			< 0.001		< 0.001		< 0.001		0.011
Han	63,891 (97.6)	72.32 ± 38.21		252.56 ± 158.68		50.66 ± 14.26		55.38 ± 13.25	
other	1,560 (2.4)	78.20 ± 39.02		288.04 ± 161.96		52.55 ± 13.53		56.49 ± 12.67	
Abstinence period, days			< 0.001		< 0.001		< 0.001		< 0.001
2–3	18,167 (27.8)	69.07 ± 35.97		217.30 ± 135.90		52.66 ± 14.50		57.41 ± 13.27	
4–5	33,592 (51.3)	74.31 ± 37.97		264.76 ± 156.13		51.23 ± 13.67		55.55 ± 12.87	
6–7	13,692 (20.9)	72.45 ± 41.36		273.44 ± 184.05		46.84 ± 14.56		52.38 ± 13.54	

**Note.** Data were given as *n* (percent) or  $\bar{x} \pm s$  as indicated. Column percentages may not add up to 100 due to rounding.  $\bar{x}$ , mean value; *s*, standardized deviation. <sup>a</sup>*P*-value was estimated using Wilcoxon rank sum test for intergroup comparisons of numerical variables.

**Supplementary Table S3.** Characteristics of the study subjects and the distribution of semen parameters in subgroup<sup>a</sup>

Characteristics	n (%)	Sperm quality ( $\bar{x} \pm s$ )			
		Sperm concentration, $\times 10^6/\text{mL}$ , $P$ -value <sup>b</sup>	Sperm count, $\times 10^6$ , $P$ -value <sup>b</sup>	Progressive motility, %, $P$ -value <sup>b</sup>	Total motility, %, $P$ -value <sup>b</sup>
All Observations	11,205 (100)	77.37 $\pm$ 35.74	271.92 $\pm$ 148.60	55.07 $\pm$ 9.53	58.73 $\pm$ 9.57
Age, years					
< 30	8,151 (72.7)	75.42 $\pm$ 34.24	269.83 $\pm$ 147.11	54.76 $\pm$ 9.44	58.41 $\pm$ 9.52
30–39	2,686 (24.0)	81.74 $\pm$ 38.82	275.36 $\pm$ 150.19	55.92 $\pm$ 9.67	59.70 $\pm$ 9.63
$\geq$ 40	368 (3.3)	88.64 $\pm$ 39.81	293.06 $\pm$ 167.13	55.64 $\pm$ 10.08	59.15 $\pm$ 9.94
Ethnicity					
Han	10,856 (96.9)	77.16 $\pm$ 35.78	271.07 $\pm$ 148.61	55.04 $\pm$ 9.51	58.71 $\pm$ 9.56
other	349 (3.1)	84.02 $\pm$ 33.76	298.41 $\pm$ 146.29	56.09 $\pm$ 9.94	59.38 $\pm$ 10.00
Abstinence period, days					
2–3	3,310 (29.5)	75.70 $\pm$ 33.51	239.99 $\pm$ 131.80	56.94 $\pm$ 9.88	60.68 $\pm$ 9.88
4–5	5,941 (53.0)	78.29 $\pm$ 36.24	279.00 $\pm$ 146.52	54.92 $\pm$ 9.35	58.46 $\pm$ 9.36
6–7	1,954 (17.5)	77.42 $\pm$ 37.71	304.48 $\pm$ 170.34	52.36 $\pm$ 8.73	56.20 $\pm$ 8.95

**Note.** Data were given as  $n$  (percent) or  $\bar{x} \pm s$  as indicated. Column percentages may not add up to 100 due to rounding.  $\bar{x}$ , mean value;  $s$ , standardized deviation. <sup>a</sup>The subgroup only included subjects with normal sperm concentration, sperm count, and motility according to the WHO reference levels for human semen parameters. <sup>b</sup> $P$ -value was estimated using Wilcoxon rank sum test for intergroup comparisons of numerical variables.

**Supplementary Table S4.** The regression coefficient (95% CIs) of semen quality associated with hot nights in sensitivity analyses at 0–90 lag days

Semen quality parameter	HNE (°C)	HND (%)	Nighttime temperature (°C)
	$\beta$ (95% CIs)	$\beta$ (95% CIs)	$\beta$ (95% CIs)
Subgroup <sup>a</sup>			
Sperm concentration, $\times 10^6$ /mL	-0.0013 (-0.0082, 0.0057)	0.0014 (-0.0007, 0.0036)	-0.0131 (-0.0388, 0.0125)
Sperm count, $\times 10^6$	-0.0011 (-0.0079, 0.0056)	0.0015 (-0.0006, 0.0036)	0.0027 (-0.0225, 0.0280)
Progressive motility, %	-0.0102 (-0.0171, -0.0033)	-0.0019 (-0.0041, 0.0003)	-0.0348 (-0.0615, -0.0081)
Total motility, %	-0.0071 (-0.0145, 0.0003)	-0.0011 (-0.0034, 0.0011)	-0.0231 (-0.0519, 0.0056)
Adjusted for $T_{\text{mean}}$ <sup>b</sup>			
Sperm concentration, $\times 10^6$ /mL	-0.0051 (-0.0130, 0.0028)	0.0032 (0.0004, 0.0061)	-0.0208 (-0.0545, 0.0128)
Sperm count, $\times 10^6$	-0.0071 (-0.0148, 0.0007)	0.0027 (-0.0001, 0.0056)	-0.0042 (-0.0375, 0.0290)
Progressive motility, %	-0.0104 (-0.0182, -0.0027)	-0.0030 (-0.0059, -0.0001)	-0.0151 (-0.0498, 0.0197)
Total motility, %	-0.0134 (-0.0236, -0.0031)	-0.0034 (-0.0068, 0.0001)	-0.0262 (-0.0694, 0.0170)
Adjusted for occupation <sup>c</sup>			
Sperm concentration, $\times 10^6$ /mL	-0.0023 (-0.0100, 0.0053)	0.0013 (-0.0010, 0.0037)	-0.0204 (-0.0484, 0.0076)
Sperm count, $\times 10^6$	-0.0026 (-0.0103, 0.0050)	0.0017 (-0.0006, 0.0041)	-0.0028 (-0.0312, 0.0255)
Progressive motility, %	-0.0108 (-0.0178, -0.0038)	-0.0022 (-0.0044, 0.0000)	-0.0352 (-0.0622, -0.0082)
Total motility, %	-0.0128 (-0.0212, -0.0045)	-0.0026 (-0.0050, -0.0002)	-0.0462 (-0.0775, -0.0150)
Adjusted for $O_3$ <sup>d</sup>			
Sperm concentration, $\times 10^6$ /mL	-0.0020 (-0.0080, 0.0039)	0.0017 (-0.0002, 0.0036)	-0.0156 (-0.0377, 0.0065)
Sperm count, $\times 10^6$	-0.0021 (-0.0080, 0.0037)	0.0019 (0.0000, 0.0037)	0.0012 (-0.0207, 0.0230)
Progressive motility, %	-0.0097 (-0.0155, -0.0038)	-0.0023 (-0.0041, -0.0004)	-0.0253 (-0.0479, -0.0027)
Total motility, %	-0.0101 (-0.0168, -0.0034)	-0.0024 (-0.0045, -0.0003)	-0.0277 (-0.0535, -0.0020)

**Note.** The combined regression coefficients and corresponding 95% confidence intervals (CIs) were estimated using linear mixed models, adjusting for abstinence period, age, ethnicity, month of semen sample, as well as average  $PM_{2.5}$  concentration, average  $NO_2$  concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; CIs, confidence intervals;  $T_{\text{mean}}$ , daily average temperature. <sup>a</sup>The subgroup only included subjects with normal sperm concentration, sperm count, and motility according to the WHO reference levels for human semen parameters. <sup>b</sup>Additionally adjusted for the average temperature (categorical variable) in the main model. <sup>c</sup>Additionally adjusted for occupational factors in the main model. <sup>d</sup>Additionally adjusted for the average  $O_3$  exposure concentration at 0–90 lag days in the main model.

**Supplementary Table S5.** The combined estimated changes and corresponding 95% confidence intervals (CIs) of semen quality associated with hot nights at the 99th percentile in sensitivity analyses

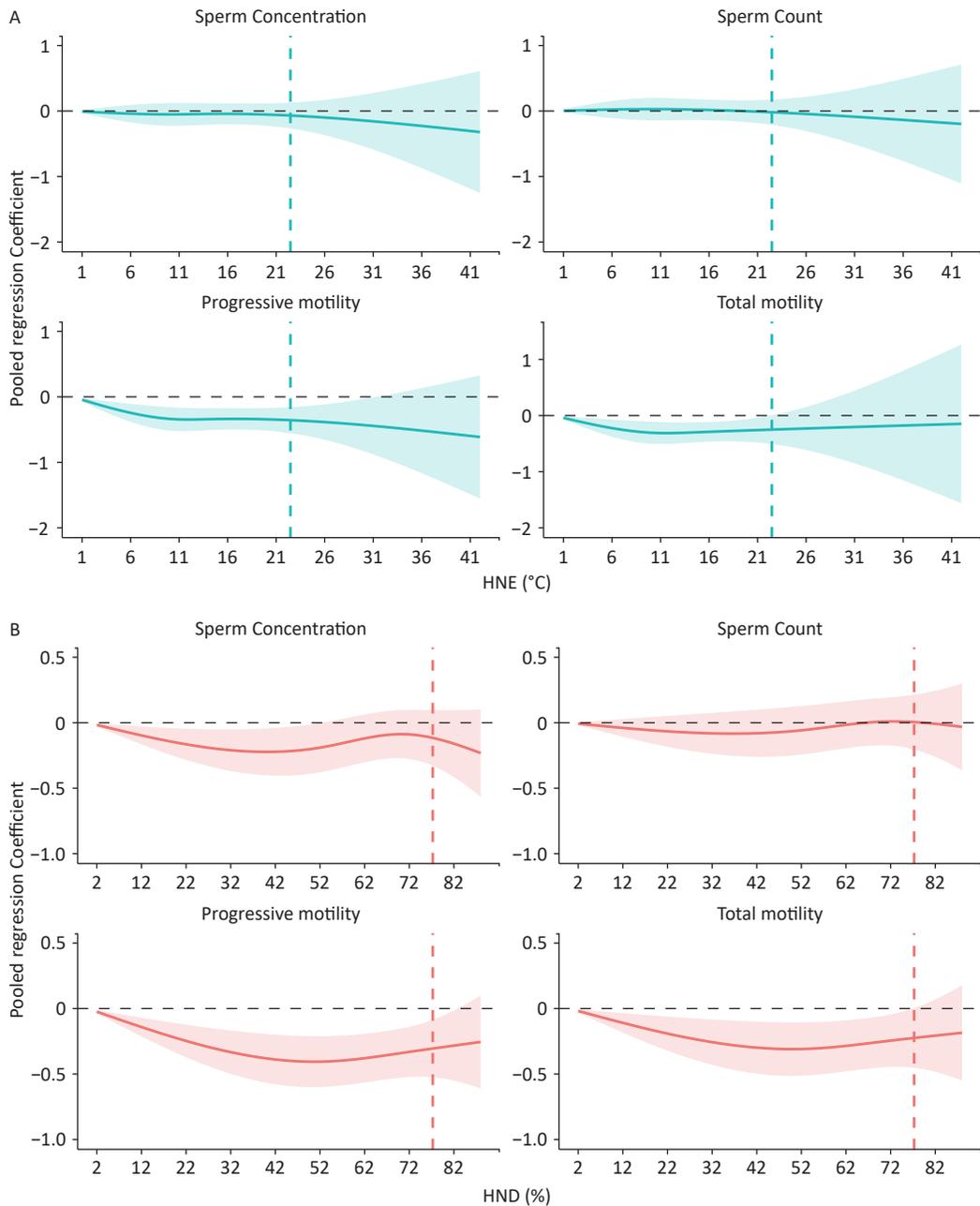
Semen quality parameter	HNE (°C)		HND (%)	
	$\beta$ (95% CIs)	$P_{\text{nonlinear}}^f$	$\beta$ (95% CIs)	$P_{\text{nonlinear}}^f$
Subgroup <sup>a</sup>				
Sperm concentration, $\times 10^6$ /mL	-0.0689 (-0.2664, 0.1287)	0.9044	-0.1157 (-0.3279, 0.0965)	0.0028
Sperm count, $\times 10^6$	-0.0188 (-0.2117, 0.1740)	0.8845	0.0052 (-0.2037, 0.2141)	0.1721
Progressive motility, %	-0.3562 (-0.5549, -0.1574)	0.0009	-0.3052 (-0.5244, -0.0859)	0.0002
Total motility, %	-0.2502 (-0.5071, 0.0067)	0.0070	-0.2242 (-0.4524, 0.0039)	0.0104
Nodes setting <sup>b</sup>				
Sperm concentration, $\times 10^6$ /mL	-0.0134 (-0.1967, 0.1700)	0.2236	-0.0564 (-0.2452, 0.1325)	0.0085
Sperm count, $\times 10^6$	0.0386 (-0.1419, 0.2191)	0.0320	0.0843 (-0.1020, 0.2706)	0.2412
Progressive motility, %	-0.2311 (-0.4130, -0.0492)	0.0124	-0.2299 (-0.4211, -0.0386)	0.0157
Total motility, %	-0.2495 (-0.4838, -0.0152)	0.0436	-0.1981 (-0.4126, 0.0164)	0.1367
Adjusted for $T_{\text{mean}}^c$				
Sperm concentration, $\times 10^6$ /mL	0.0048 (-0.0256, 0.2152)	0.0511	0.1900 (-0.0552, 0.4352)	0.0005
Sperm count, $\times 10^6$	-0.0321 (-0.02393, 0.1751)	0.0061	0.2149 (-0.0270, 0.4568)	0.0235
Progressive motility, %	-0.2744 (-0.4843, -0.0644)	0.0425	-0.2247 (-0.4728, 0.0234)	0.1381
Total motility, %	-0.3173 (-0.5902, -0.0046)	0.0986	-0.2259 (-0.5143, 0.0624)	0.3564
Adjusted for occupation <sup>d</sup>				
Sperm concentration, $\times 10^6$ /mL	0.0057 (-0.2102, 0.2217)	0.5873	-0.0895(-0.3256, 0.1466)	0.0643
Sperm count, $\times 10^6$	0.0607 (-0.1563, 0.2777)	0.1524	0.0928 (-0.1456, 0.3312)	0.5139
Progressive motility, %	-0.2931 (-0.4912, -0.0949)	0.0113	-0.3494 (-0.5728, -0.1260)	0.0029
Total motility, %	-0.3099 (-0.5792, -0.0406)	0.0223	-0.3547 (-0.6070, -0.1024)	0.0204
Adjusted for $O_3^e$				
Sperm concentration, $\times 10^6$ /mL	0.0045 (-0.1699, 0.1790)	0.1908	-0.0477 (-0.2380, 0.1426)	0.0077
Sperm count, $\times 10^6$	0.0499 (-0.1218, 0.2216)	0.0223	0.0968 (-0.0910, 0.2845)	0.2190
Progressive motility, %	-0.2499 (-0.4229, -0.0769)	0.0064	-0.2645 (-0.4577, -0.0713)	0.0104
Total motility, %	-0.2614 (-0.4878, -0.0351)	0.0289	-0.2314 (-0.4471, -0.0156)	0.1077

**Note.** The estimated changes of semen quality were assessed by including a natural cubic B-spline of hot night indices (HNE or HND), and adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average  $PM_{2.5}$  concentration, average  $NO_2$  concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; CIs, confidence intervals;  $T_{\text{mean}}$ , daily average temperature. <sup>a</sup>The subgroup only included subjects with normal sperm concentration, sperm count, and motility according to the WHO reference levels for human semen parameters. <sup>b</sup>Adjusting the cross-basis function with two internal nodes at the 50th and 75th percentiles of HNE and HND distributions referring to relevant studies; <sup>c</sup>Additionally adjusted for the average temperature (categorical variable) in the main model. <sup>d</sup>Additionally adjusted for occupational factors in the main model. <sup>e</sup>Additionally adjusted for the average  $O_3$  exposure concentration at 0–90 lag days in the main model. <sup>f</sup> $P_{\text{nonlinear}}$  means non-linear test of exposure-response curves.

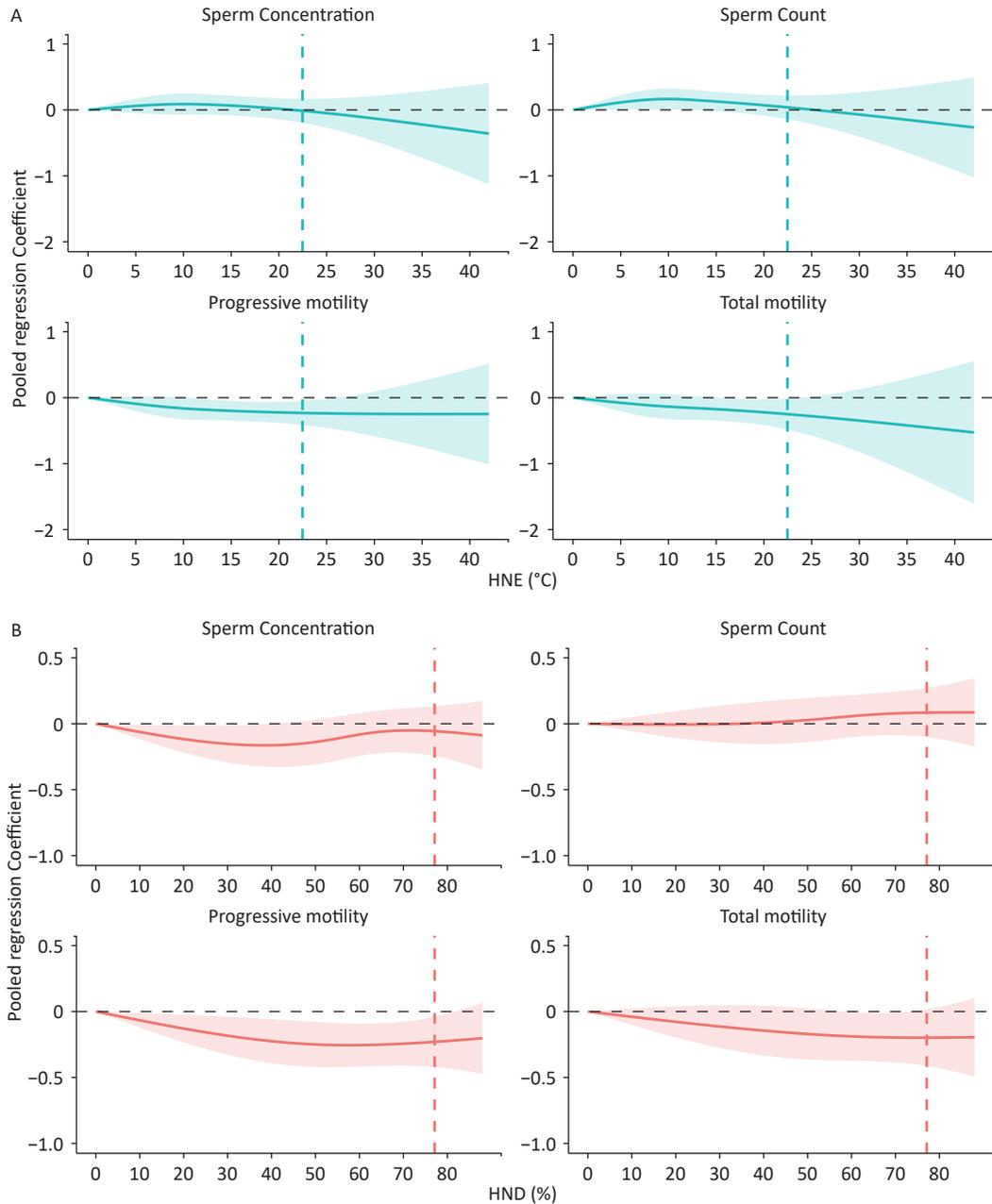
**Supplementary Table S6.** Repeated measurement data with regression coefficients (95% CIs) of semen quality associated with hot nights in six regions of China during 2014–2020

Semen quality parameter	HNE		HND		Nighttime temperature	
	$\beta$ (95% CIs)	<i>P</i> -value	$\beta$ (95% CIs)	<i>P</i> -value	$\beta$ (95% CIs)	<i>P</i> -value
Sperm concentration, $\times 10^6$ /mL	-0.0024 (-0.0122, 0.0074)	0.6343	0.0012 (-0.0015, 0.0040)	0.3694	-0.0388 (-0.0730, -0.0047)	0.0259
Sperm count, $\times 10^6$	0.0037 (-0.0062, 0.0135)	0.4649	0.0026 (0.0000, 0.0053)	0.0552	-0.0086 (-0.0432, 0.0260)	0.6275
Progressive motility, %	-0.0198 (-0.0293, -0.0103)	< 0.0001	-0.0046 (-0.0072, -0.0019)	0.0007	-0.0685 (-0.1028, -0.0342)	0.0001
Total motility, %	-0.0195 (-0.0289, -0.0100)	0.0001	-0.0048 (-0.0074, -0.0022)	0.0003	-0.0679 (-0.1021, -0.0337)	0.0001

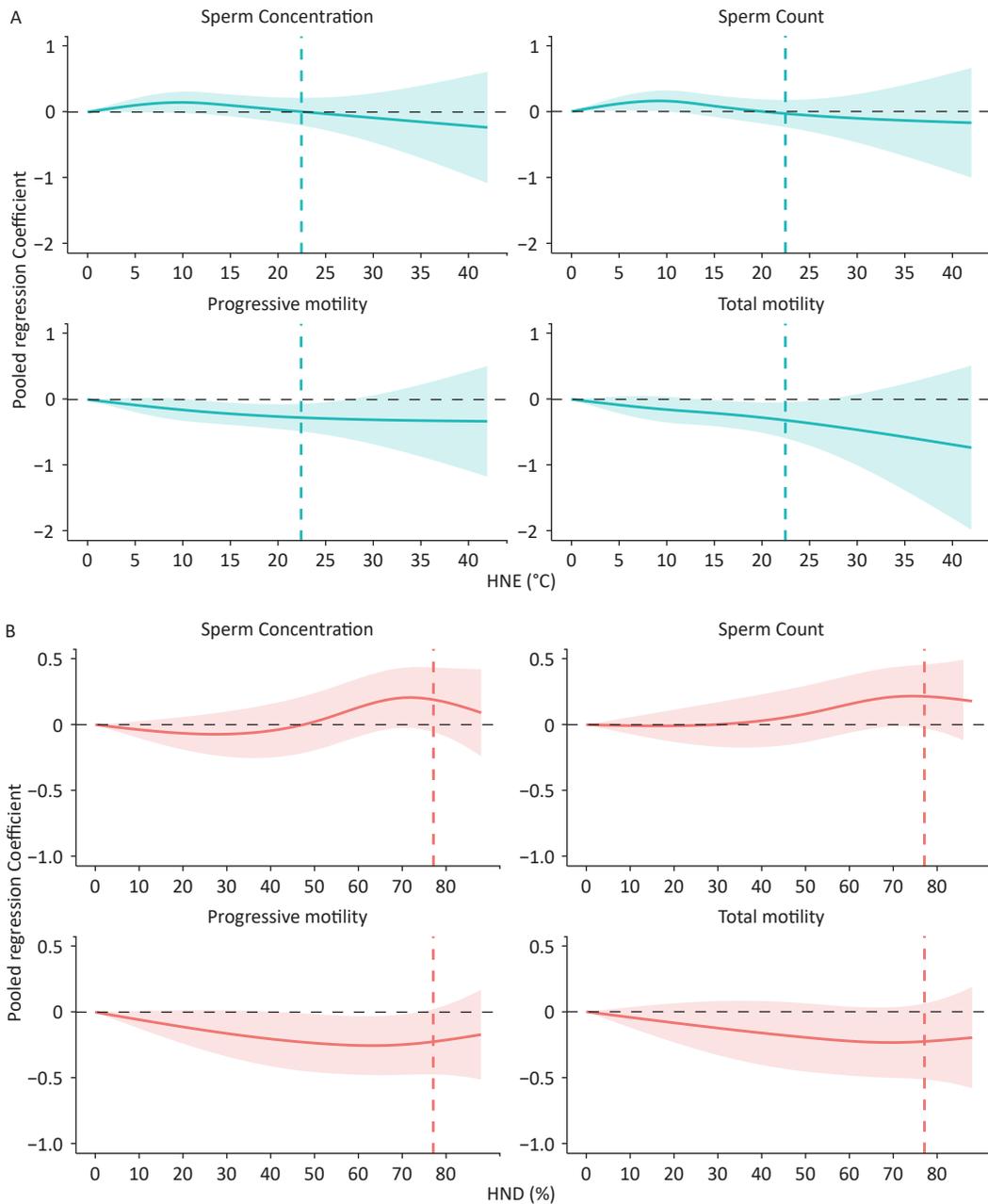
**Note.** The combined regression coefficients and corresponding 95% confidence intervals (CIs) were estimated using linear mixed models, adjusting for abstinence period, age, ethnicity, month of semen sample, as well as average PM<sub>2.5</sub> concentration, average NO<sub>2</sub> concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; CIs, confidence intervals.



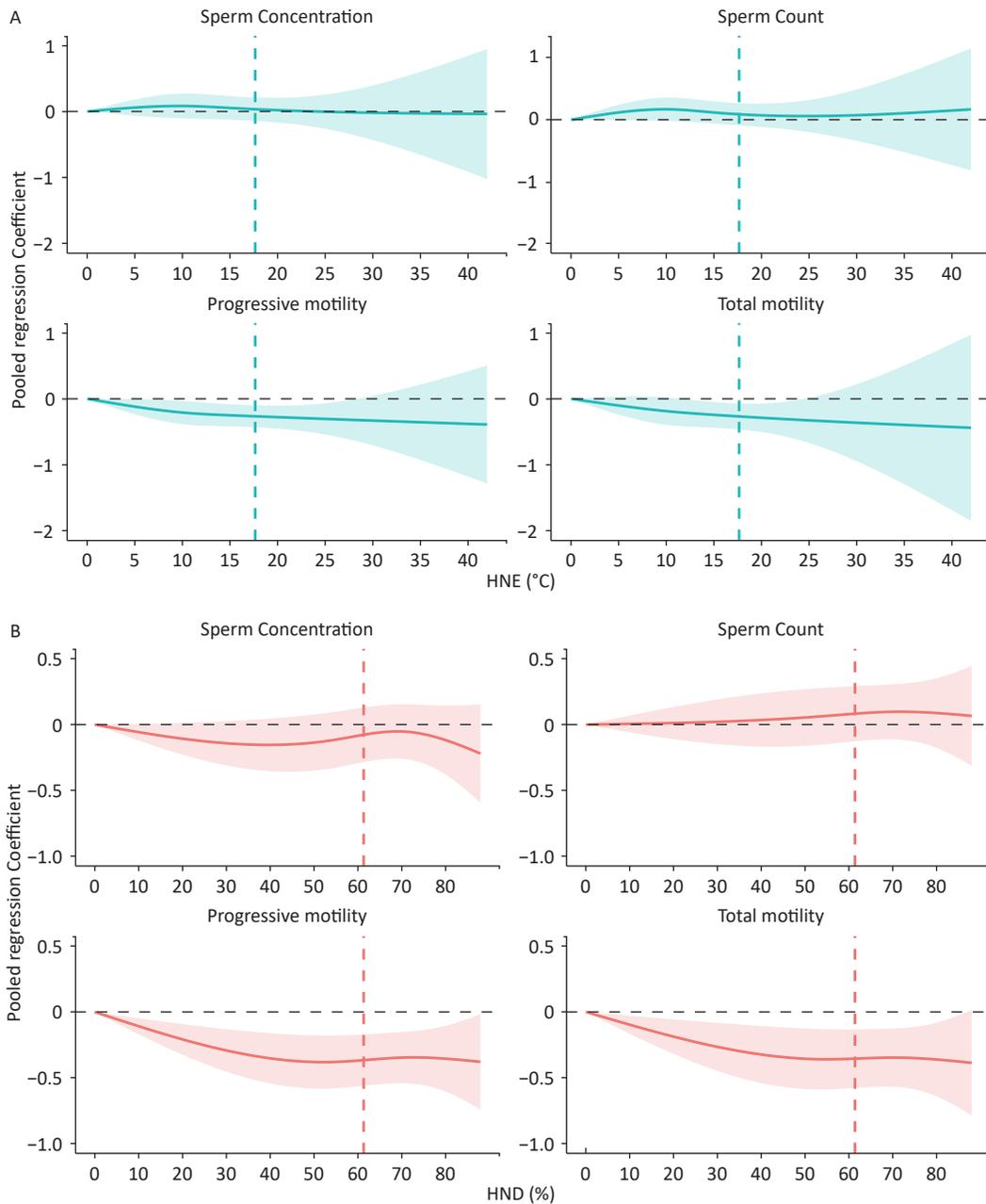
**Supplementary Figure S1.** Relationships between hot night indices (A) HNE, (B) HND and semen parameters in subgroup. The estimated changes of semen quality were accessed by including a natural cubic B-spline of hot night excess (HNE), and were adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average PM<sub>2.5</sub> concentration, average NO<sub>2</sub> concentration, and mean relative humidity during 0–90 days before the date of semen collection. The subgroup only included subjects with normal sperm concentration, sperm count, and motility according to the WHO reference levels for human semen parameters.



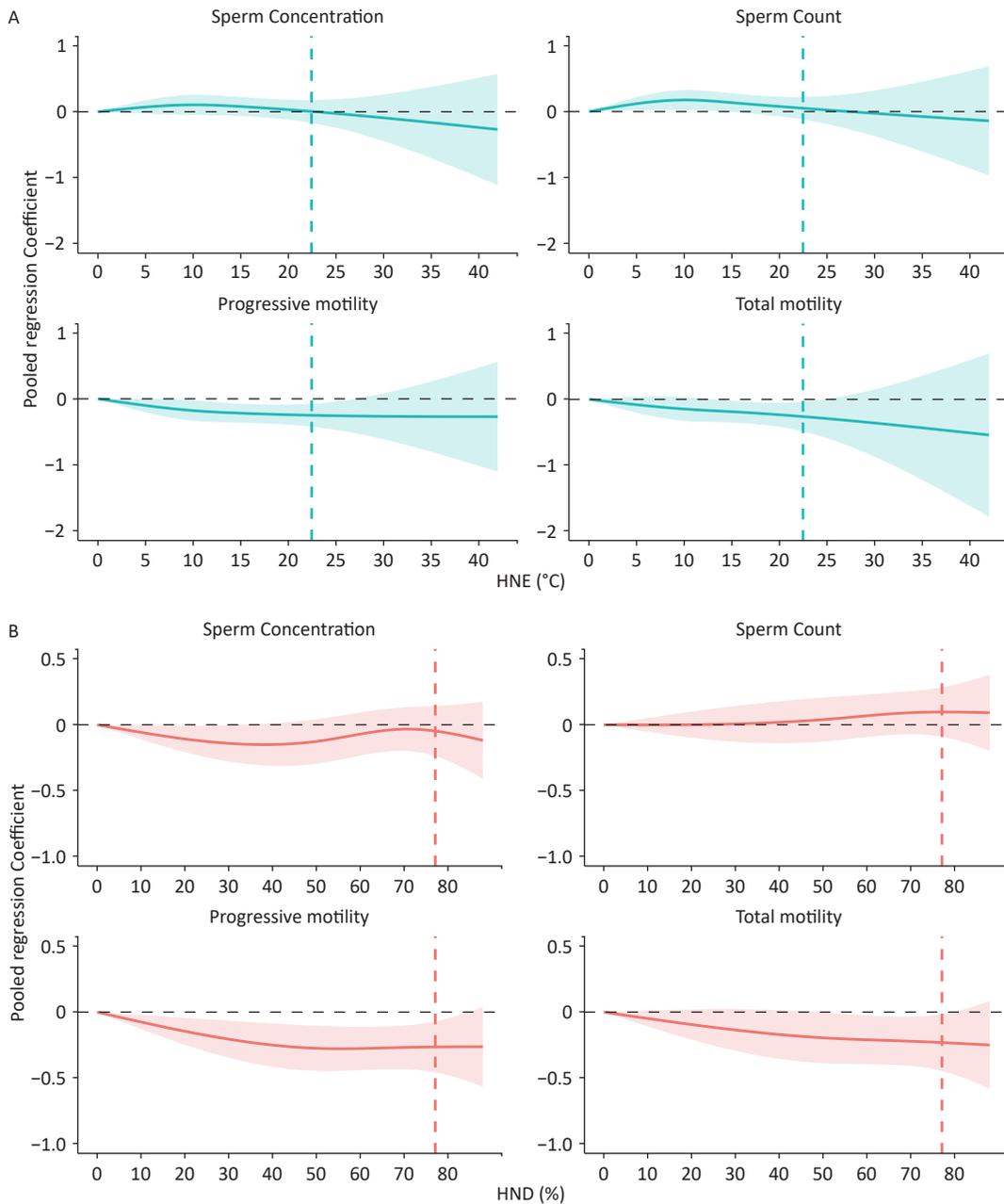
**Supplementary Figure S2.** The exposure–response associations between semen quality and hot night indices (A) HNE (B) HND, adjusted for the two internal nodes at the 50th and 75th percentiles. The estimated changes of semen quality were accessed by including a natural cubic B–spline of hot night indices (HNE or HND), and were adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average PM<sub>2.5</sub> concentration, average NO<sub>2</sub> concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; *CIs*, confidence intervals. The vertical dotted lines indicate the 99th percentile of regional warm–season hot night excess (HNE) and hot night duration (HND). Shaded areas represent corresponding 95% *CIs*.



**Supplementary Figure S3.** The exposure–response relationships between hot night indices (A) HNE, (B) HND and semen quality adjusting for daily average temperature during 0–90 lag days. The estimated changes of semen quality were accessed by including a natural cubic B–spline of hot night indices (HNE or HND), and were adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average PM<sub>2.5</sub> concentration, average NO<sub>2</sub> concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; *CIs*, confidence intervals. The vertical dotted lines indicate the 99th percentile of regional warm–season hot night excess (HNE) and hot night duration (HND). Shaded areas represent corresponding 95% *CIs*.



**Supplementary Figure S4.** The exposure–response relationships between hot night indices (A) HNE, (B) HND and semen quality adjusting for occupational factors at 0–90 lag days. The estimated changes of semen quality were accessed by including a natural cubic B–spline of hot night indices (HNE or HND), and were adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average PM<sub>2.5</sub> concentration, average NO<sub>2</sub> concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; *CIs*, confidence intervals. The vertical dotted lines indicate the 99th percentile of regional warm–season hot night excess (HNE) and hot night duration (HND). Shaded areas represent corresponding 95% *CIs*.



**Supplementary Figure S5.** The exposure–response relationships between hot night indices (A) HNE, (B) HND and semen quality with adjustment for average  $O_3$  concentration at 0–90 lag days. The estimated changes of semen quality were accessed by including a natural cubic B–spline of hot night indices (HNE or HND), and were adjusted for abstinence period, age, ethnicity, month of semen sample, as well as average  $PM_{2.5}$  concentration, average  $NO_2$  concentration, and mean relative humidity during 0–90 days before the date of semen collection. HNE, hot night excess; HND, hot night duration; *CIs*, confidence intervals. The vertical dotted lines indicate the 99th percentile of regional warm–season hot night excess (HNE) and hot night duration (HND). Shaded areas represent corresponding 95% *CIs*.