Supplementary material

The role of temperature, influenza and other local characteristics in seasonality of mortality: a population-based time-series study in Japan

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Table S1. Summary of daily mean temperature, daily cases of all-cause, circulatory, and respiratory mortality, and **weekly** cases of influenza likely illness

Prefecture/ country [a]	Daily mean temperature (℃)		All-cause mortality (n)		Circulatory mortality (n)		Respiratory mortality (n)		Influenza like illness (n)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD	Range	Mean (SD)	Range	Mean (SD)	Range
Hokkaido	9.32 (9.62)	[-11;29.6]	141.36 (21.94)	[81;220]	41.47 (8.36)	[18;79]	20.49 (6.09)	[3;55]	958.26 (2040.19)	[0;15153]
Aomori	10.7 (9.06)	[-7.5;30.1]	41.56 (8.2)	[16;79]	12.64 (3.95)	[1;28]	5.94 (2.73)	[0;19]	259.68 (566.2)	[0;3591]
Akita	12.14 (9.14)	[-5.5;31.6]	37.03 (7.55)	[15;64]	11.21 (3.75)	[1;27]	5.5 (2.6)	[0;19]	241.43 (517)	[0;4180]
Iwate	10.64 (9.46)	[-8.9;29.3]	40.4 (8.44)	[15;85]	13.49 (4.37)	[1;32]	5.89 (2.68)	[0;19]	273.48 (564.55)	[0;3716]
Miyagi	12.84 (8.38)	[-4.5;31.2]	55.3 (11.21)	[22;152]	17.14 (5.11)	[2;43]	7.57 (3.26)	[0;29]	400.31 (857.1)	[0;5417]
Yamagata	12.1 (9.43)	[-5.8;30.5]	36.91 (7.58)	[13;68]	11.59 (3.81)	[0;29]	5.49 (2.63)	[0;18]	209.39 (444.9)	[0;2795]
Niigata	14.17 (8.76)	[-2.8;31.8]	68.63 (12.22)	[31;112]	21.17 (5.66)	[4;45]	9.27 (3.5)	[0;26]	467.68 (1057.89)	[0;7472]
Fukushima	13.42 (8.89)	[-4.2;31.4]	58.49 (11.3)	[23;114]	18.98 (5.55)	[5;44]	8.61 (3.43)	[0;29]	350.57 (736.63)	[0;4293]
Toyama	14.57 (8.89)	[-2.8;33.1]	30.8 (6.97)	[11;59]	8.72 (3.25)	[1;24]	4.95 (2.46)	[0;16]	197.35 (433.32)	[0;3042]
Nagano	12.28 (9.53)	[-6.7;30]	59.97 (11.51)	[26;107]	19.68 (5.61)	[4;48]	8.38 (3.48)	[0;23]	424.98 (927.86)	[0;6713]
Ishikawa	15.07 (8.66)	[-2.6;32.4]	29.71 (6.78)	[9;58]	8.78 (3.28)	[0;26]	4.65 (2.37)	[0;16]	222.14 (503.98)	[0;3450]
Tochigi	14.39 (8.56)	[-2.5;31.7]	50.11 (10.49)	[19;95]	16.02 (5.1)	[4;37]	7.32 (3.21)	[0;25]	263.1 (595.1)	[0;3112]
Gunma	15.04 (8.6)	[-1.7;32.6]	51.57 (10.8)	[20;101]	15.74 (4.96)	[0;41]	8.5 (3.55)	[0;27]	393.01 (863.12)	[0;5616]
Ibaraki	14.15 (8.23)	[-1.7;31]	73.38 (14.37)	[31;136]	22.52 (6.5)	[2;51]	10.77 (4.32)	[0;31]	395.03 (908.36)	[0;5926]
Fukui	14.87 (8.94)	[-1.8;31.9]	21.69 (5.62)	[6;45]	6.35 (2.78)	[0;18]	3.57 (2.07)	[0;13]	176.7 (401.64)	[0;3054]
Saitama	15.53 (8.47)	[-0.9;33.7]	138.85 (27.86)	[65;258]	41.24 (10.6)	[13;97]	20.3 (7.16)	[3;58]	1139.33 (2572)	[0;15454]
Tokyo	16.69 (7.93)	[0.3;33.2]	265.37 (41.16)	[166;434]	76.17 (15.73)	[36;147]	38.71 (10.36)	[11;96]	1016.52 (2578.95)	[0;18939]
Yamanashi	15.12 (8.69)	[-2.1;31.8]	23.31 (6)	[7;52]	6.82 (2.9)	[0;20]	3.46 (2.01)	[0;16]	144.31 (310.05)	[0;1812]
Chiba	16.3 (7.76)	[0.3;32.1]	126.11 (24.2)	[64;216]	38.5 (9.97)	[13;88]	17.97 (6.22)	[2;58]	891.29 (2020.46)	[0;12096]
Tottori	15.22 (8.54)	[-3.1;32]	17.86 (4.84)	[5;38]	5.38 (2.49)	[0;16]	2.54 (1.66)	[0;11]	113.05 (238.68)	[0;1543]
Shimane	15.26 (8.27)	[-3.3;32.2]	23.8 (5.83)	[6;48]	6.92 (2.91)	[0;23]	3.72 (2.07)	[0;14]	125.38 (276.71)	[0;1979]
Gifu	16.22 (8.69)	[-1.7;32.7]	52.28 (10.68)	[21;99]	15.57 (4.93)	[3;36]	8.05 (3.35)	[0;23]	339.83 (715.25)	[0;4339]
Kanagawa	16.28 (7.67)	[0.3;32.2]	170.3 (31.31)	[94;297]	47.51 (10.56)	[18;101]	24.47 (7.72)	[3;65]	1276.81 (3000.95)	[0;17813]
Aichi	16.26 (8.57)	[-1.5;32.7]	148.39 (26.39)	[81;236]	41.47 (9.81)	[16;80]	21.5 (6.99)	[5;52]	1026.52 (2284.16)	[0;12493]
Kyoto	16.23 (8.71)	[-1.2;32.6]	62.27 (11.61)	[29;119]	18.01 (5.4)	[4;45]	9.63 (3.69)	[0;32]	403.21 (882.09)	[0;5518]

Table S1. Continued

Prefecture/ country	Daily mean temperature (℃)		All-cause mortality (n)		Circulatory mortality (n)		Respiratory mortality (n)		Influenza like illness (n)	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Shiga	15.1 (8.64)	[-2.1;31.8]	29.51 (7.11)	[9;60]	8.57 (3.37)	[0;22]	4.56 (2.35)	[0;18]	218.49 (484.12)	[0;2675]
Shizuoka	16.92 (7.45)	[1.7;31.9]	91.42 (18.13)	[45;172]	27.52 (7.56)	[9;62]	12.86 (4.84)	[2;36]	598.14 (1351.69)	[0;8255]
Mie	16.37 (8.21)	[-0.4;33.5]	47.71 (10.07)	[21;95]	13.97 (4.56)	[2;33]	7.12 (3.18)	[0;24]	331.76 (728.13)	[0;3989]
Hyogo	17.08 (8.24)	[-0.8;32.5]	131.5 (22.43)	[70;265]	36.03 (9.04)	[10;75]	19.74 (6.38)	[3;49]	793.55 (1722.72)	[0;10287]
Nara	15.19 (8.5)	[-1.7;30.8]	33.11 (7.65)	[12;62]	9.81 (3.76)	[0;28]	5.16 (2.56)	[0;17]	184.89 (412.67)	[0;2379]
Osaka	17.17 (8.36)	[-0.1;32.7]	195.43 (31.77)	[113;341]	52.28 (12.09)	[18;115]	30.9 (9.42)	[7;75]	1017.19 (2175.46)	[0;13525]
Okayama	16.52 (8.61)	[-1.7;32.3]	51.94 (10.18)	[19;92]	15.1 (4.7)	[1;34]	9.2 (3.64)	[0;26]	321.47 (729.3)	[0;4974]
Hiroshima	16.5 (8.43)	[-2;31.8]	72.18 (13.13)	[33;146]	20.79 (6)	[4;47]	11.62 (4.21)	[0;34]	441.89 (988.89)	[0;6087]
Kagawa	16.8 (8.37)	[-0.4;33]	28.54 (6.77)	[8;58]	8.28 (3.36)	[0;25]	5.04 (2.47)	[0;16]	187.73 (431.76)	[0;2632]
Wakayama	16.94 (8.12)	[0;32.7]	31.17 (7.11)	[9;73]	9.02 (3.47)	[0;28]	4.9 (2.48)	[0;16]	173.35 (381.83)	[0;2479]
Yamaguchi	15.79 (8.44)	[-4.5;31]	45.67 (8.95)	[20;82]	13.69 (4.43)	[2;32]	7.89 (3.25)	[0;28]	331.05 (769.8)	[0;5183]
Tokushima	16.85 (8)	[-1;32.6]	24.18 (5.89)	[8;51]	6.95 (2.88)	[0;20]	4.2 (2.26)	[0;15]	143.77 (329.5)	[0;2089]
Ehime	16.79 (8.04)	[-0.7;31.7]	42.87 (8.81)	[15;81]	13.42 (4.42)	[3;34]	6.8 (2.98)	[0;20]	263.9 (577.75)	[0;3750]
Fukuoka	17.35 (7.86)	[-0.8;32.8]	121.01 (19.83)	[69;210]	30.39 (7.36)	[11;73]	20.15 (6.46)	[4;57]	1025.85 (2276.78)	[0;12597]
Kochi	17.37 (7.75)	[-0.1;32.1]	25.27 (6.07)	[9;52]	7.92 (3.12)	[0;21]	4.2 (2.3)	[0;18]	205.81 (464.68)	[0;3201]
Oita	16.87 (7.76)	[-0.3;31.7]	34.24 (7.59)	[12;71]	10.03 (3.64)	[0;26]	5.89 (2.77)	[0;21]	316.35 (714.1)	[0;4478]
Saga	16.9 (8.22)	[-2.5;32.3]	23.97 (5.91)	[6;50]	6.67 (2.81)	[0;18]	4.1 (2.24)	[0;18]	186.74 (412.58)	[0;2778]
Kumamoto	17.31 (8.28)	[-1.8;31.7]	50.33 (10.24)	[20;95]	14.6 (4.69)	[1;35]	8.54 (3.55)	[0;31]	346.29 (811.45)	[0;5887]
Nagasaki	17.43 (7.64)	[-0.8;31.9]	41.9 (8.5)	[19;75]	11.99 (4.01)	[1;32]	7.08 (3.05)	[0;23]	337.01 (757.91)	[0;4798]
Miyazaki	17.77 (7.4)	[0.8;31.6]	31.75 (7.46)	[11;67]	9.72 (3.65)	[1;25]	5.28 (2.67)	[0;21]	356.01 (800.59)	[0;5875]
Kagoshima	18.85 (7.44)	[0.5;31.7]	53.03 (10.42)	[22;112]	16.1 (4.92)	[3;43]	9.4 (3.88)	[0;38]	436.56 (969.33)	[0;7309]
Okinawa	23.29 (4.68)	[10.3;31.1]	25.95 (6.33)	[6;53]	6.67 (2.78)	[0;21]	4.36 (2.26)	[0;15]	404.6 (716.61)	[0;5197]

[a] Prefectures was ordered by latitude from high to low.

[b] Daily mortality on the day of the Great East Japan Earthquake (11 March 2011) was excluded from our analysis.

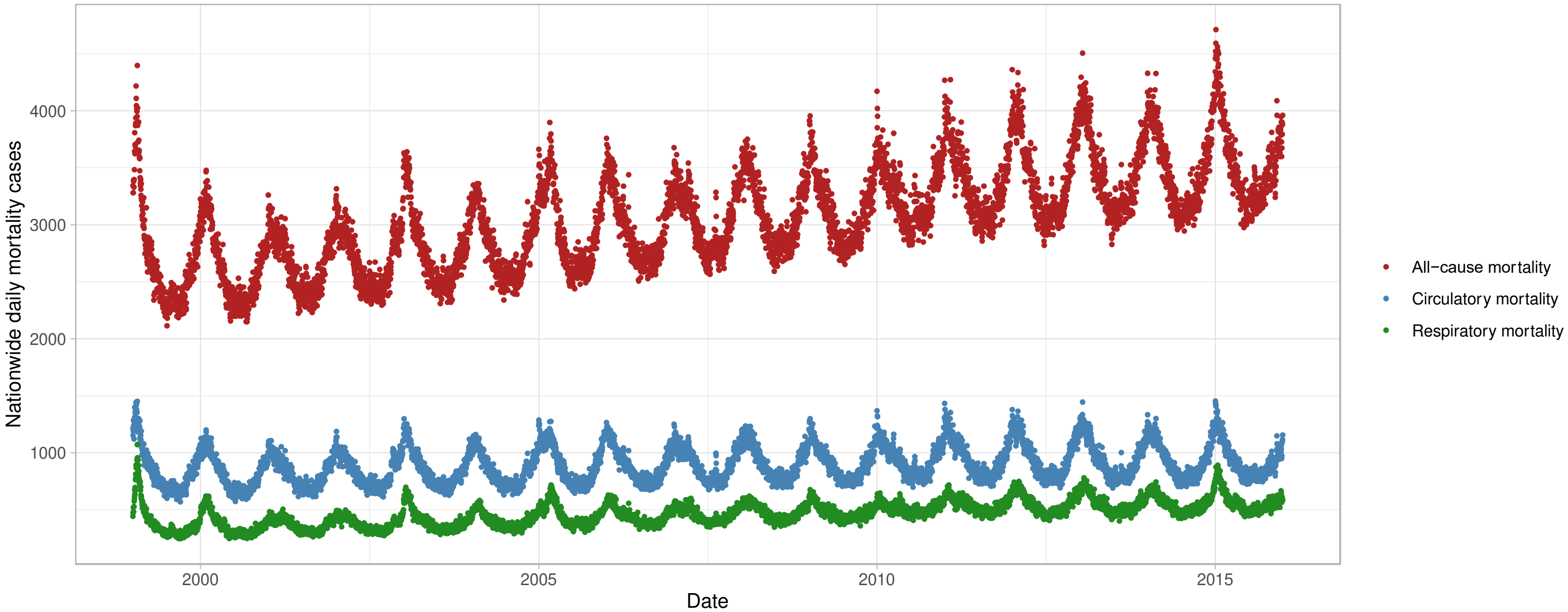

Figure S1. Time series of national wide daily mortality cases from all-cause, circulatory, respiratory disease and influenza between April 1999 and 2015

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Summary of data collection on prefecture-specific indicators on climate, demographics, socioeconomic factors, and healthcare capacity

We computed the annual mean temperature and relative humidity for each prefecture averaged from 1999 to 2015. For demographic indicators, we collected yearly data on population density and the proportion of population aged ≥65 years for each prefecture for 1972-2012 from the Statics Bureau of the Ministry of Internal Affairs and Communications of Japan. We collected information on socioeconomic indicators from Statistics Bureau of the Ministry of Internal Affairs and Communications of Japan,[1,2] including saving and income available every 5 years for 1974-2009, Gini index (a measure of income inequality) available every 5 years for 1979-2009, consumer price index (CPI) from 1972 to 2009, economic power index (EPI, a measure of the wealth of a prefecture) from 2003 to 2015, and the prevalence of air conditioning for households with two persons or more from 1972 to 2009. We extracted the number of registered physicians, nurses and hospital beds per 10K population in 1975 and 2004 from the Survey of Medical Institutions and Hospital Report conducted by the Ministry of Health, Labour and Welfare.[3] For each indicator, we computed the averaged value across the years 1999-2015 for each prefecture.

1. Satistics Bureau of the Ministry of Internal Affairs and Communications of Japan. 2015. Statistics, Consumer Price Index.
2. National Survey of Family Income and Expenditure Definitions of Terms Webpage [in Japanese]. Statics Bureau of the Ministry of Internal Affairs and Communications of Japan. 2009.
3. Survey of Medical Institutions. [WWW Document]. Health Statistics Office Ministry of Health Labor and Welfare Japan. http://www.mhlw.go.jp/english/ database/db-hss/smi.html (accessed 10.1.14.). Published 2010.

Table S2. Summary of Annual Values Across the Years (1999-2015) for Each Indicator

Indicators	Mean (SD)	Median [interquartile range]	Range
Temperature (℃)	15.55 (2.34)	16.03 [14.64; 16.91]	[8.4; 23.55]
Relative humidity (%)	68.64 (3.61)	68.42 [65.52; 72.08]	[57.51; 79.96]
Density (population/km^2)	0.003 (0.002)	0.002 [0.001; 0.003]	[0.0006; 0.013]
% population ≥ 65 years	0.22 (0.06)	0.22 [0.20; 0.25]	[0.12; 0.31]
Savings (million yen)	14.49 (5.14)	14.97 [12.24; 16.47]	[5.07; 19.73]
Income (million yen)	6.88 (1.77)	6.84 [6.35; 7.45]	[4.56; 8.94]
Consumer price index	97.65 (17.1)	97.4 [96.6; 98.60]	[94.6; 103.30]
Gini index	0.30 (0.02)	0.30 [0.29; 0.31]	[0.27; 0.35]
Economic power index (%)	0.47 (0.21)	0.42 [0.31; 0.57]	[0.20; 1.41]
Physicians (number per 10k population)	5.60 (4.98)	3.60 [4.89; 5.93]	[1.62; 34.46]
Nurses (number per 10k population)	15.04 (10.29)	10.41 [7.82; 15.88]	[4.09; 68.00]
Hospital beds (number per 10K population)	34.88 (26.72)	23.81 [17.93; 36.86]	[9.11; 130.48]
Air conditioning prevalence (%)	85.9 (31.60)	92.6 [86.0; 95.7]	[8.30; 99.40]

Table S3. Prefecture-specific summary of annual value across the years 1999-2015 for all indicators (mean (SD))

Prefecture/ country	Temperature (℃)	Relative humidity (%)	Density (population/km²)	% population ≥ 65 years	Savings (million yen)	Income (million yen)	CPI	Gini index	EPI (%)	Physicians (number per 10k population)	Nurses (number per 10k population)	Hospital beds (number per 10K population)	AC (%)
Hokkaido	9.26(0.38)	68.81(2.07)	0.0056(1e-04)	0.22(0.03)	11.64(0.15)	6.02(0.54)	97.13(1.2)	0.29(0.01)	0.38(0.02)	11.87(0.47)	37.78(4.15)	106.68(1.57)	13.23(3.46)
Aomori	10.64(0.4)	74.78(1.9)	0.0014(0)	0.23(0.03)	9.92(0.91)	5.96(0.3)	96.7(1.09)	0.3(0.01)	0.3(0.03)	2.52(0)	8.84(0.56)	19.96(0.46)	43.77(7.82)
Akita	12.11(0.28)	72.64(0.9)	0.0011(0)	0.27(0.02)	10.82(0.79)	6.51(0.62)	98.6(1.48)	0.29(0.01)	0.27(0.02)	2.2(0.06)	7.6(0.59)	17.58(0.31)	66.8(11.06)
Iwate	10.57(0.34)	73.31(1.37)	0.0014(0)	0.25(0.02)	12.29(0.23)	6.53(0.87)	97.33(0.94)	0.3(0.01)	0.29(0.02)	2.48(0.02)	10.18(0.69)	20.45(0.76)	45.5(10.4)
Miyagi	12.78(0.4)	71.22(1.25)	0.0024(0)	0.2(0.02)	11.87(0.34)	6.89(0.26)	98.05(1.4)	0.3(0.02)	0.51(0.03)	4.62(0.2)	12(1.44)	26.42(0.25)	67.99(4.46)
Yamagata	12.07(0.33)	74.27(1.31)	0.0012(0)	0.26(0.02)	12.36(0.49)	7.21(0.67)	96.85(0.84)	0.3(0.02)	0.31(0.02)	2.37(0.09)	7.94(0.69)	15.12(0.16)	76.14(6.09)
Niigata	14.19(0.29)	70.69(1.55)	0.0024(0)	0.24(0.02)	15.21(0.86)	7.38(0.64)	97.96(1.22)	0.3(0.01)	0.4(0.03)	4.34(0.09)	13.93(1.31)	30.32(0.04)	91.6(4.22)
Fukushima	13.36(0.37)	68.79(0.92)	0.0021(1e-04)	0.23(0.02)	12.46(0.38)	6.88(0.65)	97.08(1.07)	0.31(0.01)	0.42(0.03)	3.72(0.05)	11.22(1.01)	30.95(1.36)	64.27(10.34)
Toyama	14.56(0.32)	77.2(1.74)	0.0011(0)	0.24(0.02)	16.33(0.62)	8.08(0.84)	98.15(1.53)	0.3(0.02)	0.42(0.06)	2.51(0.09)	7.88(0.87)	18.34(0.01)	93.67(2.89)
Nagano	12.25(0.3)	71.31(1.55)	0.0022(0)	0.24(0.02)	15.57(0.71)	7.12(0.71)	98.11(1.21)	0.28(0.01)	0.44(0.04)	4.08(0.19)	13.78(1.49)	25.03(0.11)	54.38(7.79)
Ishikawa	15.06(0.3)	70.05(1.91)	0.0012(0)	0.21(0.02)	16.57(1.16)	7.71(0.96)	98.56(1.12)	0.29(0)	0.44(0.05)	2.9(0.12)	8.89(0.73)	20.41(0.58)	92.95(3.05)
Tochigi	14.34(0.34)	69.09(2.2)	0.002(0)	0.2(0.02)	15.62(0.66)	7.46(0.33)	96.8(1.4)	0.3(0.01)	0.58(0.07)	3.91(0.18)	9.57(1.27)	22.67(0.07)	89.19(2.63)
Gunma	14.98(0.34)	61.18(1.76)	0.002(0)	0.21(0.02)	15.58(1.06)	6.85(0.54)	98.26(1.46)	0.3(0.01)	0.55(0.05)	3.98(0.17)	10.03(1.65)	25.32(0.04)	89.03(2.93)
Ibaraki	14.08(0.39)	72.75(0.85)	0.003(0)	0.2(0.03)	15.35(0.57)	7.44(0.95)	95.5(0.98)	0.3(0.01)	0.6(0.07)	4.37(0.17)	12.01(1.43)	33.23(0.45)	89.75(3.88)
Fukui	14.85(0.28)	74.7(1.86)	8e-04(0)	0.23(0.02)	18.63(1.15)	8.19(0.72)	98.05(1.51)	0.3(0.01)	0.38(0.04)	1.72(0.05)	5.12(0.57)	12.24(0.22)	95.13(1.62)
Saitama	15.49(0.34)	64.24(2.26)	0.0071(1e-04)	0.17(0.03)	15.16(0.87)	7.38(0.62)	97.09(1.53)	0.29(0.01)	0.7(0.06)	8.95(0.71)	23.78(3.55)	61.53(1.06)	97.33(0.96)
Tokyo	16.67(0.36)	59.7(1.51)	0.0126(4e-04)	0.19(0.02)	18.18(1.42)	7.99(0.25)	99.56(1.67)	0.31(0)	1.21(0.14)	33.31(1.63)	64.5(4.94)	130.07(0.57)	96.44(1.2)
Yamanashi	15.08(0.3)	63.11(1.55)	9e-04(0)	0.22(0.02)	13.92(1.39)	6.79(0.68)	96.91(0.99)	0.29(0.02)	0.38(0.05)	1.69(0.02)	4.98(0.53)	11.52(0.33)	73.15(6.8)
Chiba	16.24(0.39)	68.32(1.6)	0.0061(1e-04)	0.18(0.03)	16.19(0.2)	7.53(0.81)	98.23(1.68)	0.3(0.01)	0.72(0.07)	8.8(0.53)	22.91(2.73)	56.24(0.03)	93.66(1.69)
Tottori	15.19(0.29)	72.91(1.3)	6e-04(0)	0.24(0.02)	15.58(0.65)	6.81(0.67)	97.94(1.25)	0.3(0)	0.25(0.02)	1.66(0.07)	4.41(0.44)	9.15(0.06)	90.29(4.57)
Shimane	15.24(0.28)	74.31(1.45)	7e-04(0)	0.27(0.02)	14.25(0.86)	6.96(0.72)	96.61(0.78)	0.3(0.02)	0.23(0.02)	1.85(0.06)	5.57(0.51)	11.97(0.21)	89.79(5.51)
Gifu	16.18(0.3)	65.69(2.68)	0.0021(0)	0.21(0.02)	17.53(0.51)	7.66(0.86)	97.35(1.76)	0.3(0.01)	0.49(0.05)	3.54(0.1)	10.18(1.01)	21.05(0.26)	90.63(4.4)
Kanagawa	16.22(0.36)	65.11(1.62)	0.0088(2e-04)	0.17(0.03)	17.92(0.65)	7.78(0.6)	97.7(1.03)	0.3(0.01)	0.89(0.07)	14.7(0.72)	37.79(3.69)	75.2(0.55)	94.64(1.46)
Aichi	16.23(0.34)	65.22(2.84)	0.0073(2e-04)	0.18(0.02)	17.99(1.16)	7.7(0.45)	97.96(1.2)	0.3(0)	0.97(0.09)	12.97(0.47)	33.84(4.21)	69.96(0.03)	96.72(0.97)
Kyoto	16.19(0.28)	64.26(2)	0.0026(0)	0.21(0.03)	15.65(0.9)	6.64(0.83)	97.09(1.02)	0.29(0.01)	0.56(0.07)	7.17(0.11)	16.99(1.48)	37.17(0.42)	97.19(1.66)
Shiga	15.07(0.26)	73.87(1.46)	0.0014(0)	0.18(0.02)	16.75(0.7)	7.42(0.54)	97.59(1.18)	0.29(0.01)	0.53(0.07)	2.63(0.18)	8.37(1.16)	14.14(0.63)	95.43(1.49)
Shizuoka	16.9(0.3)	68.26(1.74)	0.0038(0)	0.21(0.03)	16.73(0.53)	7.45(0.65)	97.06(1.33)	0.3(0.01)	0.7(0.05)	6.43(0.29)	19.68(2.15)	39.74(0.74)	90.19(3.06)

Table S3. Continued

Prefecture/ country	Temperature (℃)	Relative humidity (%)	Density (population/km²)	% population ≥ 65 years	Savings (million yen)	Income (million yen)	CPI	Gini index	EPI (%)	Physicians (number per 10k population)	Nurses (number per 10k population)	Hospital beds (number per 10K population)	AC (%)
Mie	16.35(0.3)	67.67(2.16)	0.0019(0)	0.22(0.02)	17.55(1.8)	7.45(0.65)	96.24(0.83)	0.28(0)	0.54(0.07)	3.38(0.08)	9.3(1.17)	21.22(0.07)	94.91(1.84)
Hyogo	17.08(0.29)	65.15(1.93)	0.0056(0)	0.2(0.03)	16(0.65)	7.01(0.52)	98.18(1.95)	0.3(0.01)	0.55(0.07)	11.22(0.49)	30.33(3.37)	64.77(0.49)	95.64(1.59)
Nara	15.16(0.29)	72.17(1.47)	0.0014(0)	0.21(0.03)	18.02(1.78)	7.26(0.69)	99.24(2.2)	0.3(0.01)	0.39(0.05)	2.81(0.15)	7.23(0.82)	16.19(0.88)	97.19(1.89)
Osaka	17.19(0.32)	62.81(1.12)	0.0088(0)	0.19(0.03)	14.5(0.48)	6.62(0.7)	99.34(1.9)	0.32(0.02)	0.75(0.05)	21.07(0.69)	44.41(6.91)	113.25(3.26)	97.5(0.59)
Okayama	16.57(0.29)	65.53(1.56)	0.0019(0)	0.23(0.02)	16.77(0.56)	7.07(0.67)	97.51(0.81)	0.3(0.01)	0.48(0.07)	4.86(0.27)	14.71(1.4)	31.45(0.45)	94.55(1.98)
Hiroshima	16.48(0.28)	67.24(2.45)	0.0029(0)	0.21(0.02)	16.13(1.18)	6.9(0.34)	97.44(1.08)	0.3(0.01)	0.54(0.07)	6.7(0.16)	17.77(2.04)	42.23(0.33)	93.33(2.63)
Kagawa	16.8(0.28)	65.55(1.47)	0.001(0)	0.24(0.02)	18.52(1.26)	6.95(0.53)	97.44(1)	0.29(0.01)	0.43(0.05)	2.51(0.04)	7.55(0.52)	17.36(0.4)	96.75(1.47)
Wakayama	16.92(0.31)	64.22(1.73)	0.001(0)	0.24(0.03)	15.19(1.03)	6.24(0.7)	96.62(1.17)	0.3(0)	0.3(0.04)	2.54(0.09)	5.8(0.72)	14.84(0.25)	95.35(3.3)
Yamaguchi	15.81(0.25)	70.19(1.53)	0.0015(0)	0.25(0.02)	13.95(0.73)	6.3(0.36)	98.89(1.38)	0.29(0.01)	0.41(0.05)	3.53(0.06)	10.57(0.97)	28.29(0.22)	91.97(2.59)
Tokushima	16.86(0.3)	66.08(1.49)	8e-04(0)	0.25(0.02)	16.1(1.28)	6.77(0.58)	97.19(0.89)	0.33(0.01)	0.31(0.02)	2.26(0.05)	6.08(0.39)	16.22(0.56)	94.51(3.19)
Ehime	16.8(0.28)	65.35(2.18)	0.0015(0)	0.24(0.02)	13.8(1.41)	6.11(0.32)	97.26(0.86)	0.3(0.01)	0.37(0.04)	3.4(0.06)	10.91(0.81)	23.81(0)	92.68(3.68)
Fukuoka	17.33(0.28)	65.6(1.58)	0.0051(0)	0.2(0.02)	12.55(0.73)	6.49(0.36)	98.16(1.94)	0.31(0.01)	0.58(0.04)	13.19(0.52)	35.67(3.32)	89.87(1.1)	95.35(1.66)
Kochi	17.39(0.32)	68.63(1.23)	8e-04(0)	0.26(0.02)	13.95(2.37)	6.22(0.69)	97.43(1.26)	0.32(0.01)	0.23(0.02)	2.16(0.05)	6.48(0.71)	20.05(0.56)	88.7(4.85)
Oita	16.9(0.3)	66.88(1.82)	0.0012(0)	0.25(0.02)	12.17(0.27)	6.08(0.55)	97.08(1.06)	0.3(0.01)	0.33(0.04)	2.82(0.1)	8.78(0.95)	21.09(0.22)	88.78(4.67)
Saga	16.86(0.27)	67.71(1.68)	9e-04(0)	0.23(0.02)	12.14(1.08)	6.84(0.65)	98.58(1.54)	0.29(0.01)	0.31(0.03)	1.95(0.05)	6.44(0.57)	15.47(0.05)	93.39(4.24)
Kumamoto	17.34(0.36)	68.2(1.65)	0.0018(0)	0.24(0.02)	10.85(0.52)	6.27(0.55)	97.84(1.16)	0.31(0.01)	0.36(0.04)	4.58(0)	14.54(1.4)	36.53(0.44)	90.52(3.13)
Nagasaki	17.45(0.31)	68.71(1.9)	0.0015(0)	0.24(0.02)	11.01(0.22)	6.02(0.58)	97.86(0.97)	0.31(0.02)	0.27(0.03)	3.78(0.2)	10.92(1.21)	28.45(0.91)	93.37(2.21)
Miyazaki	17.78(0.32)	72.24(1.44)	0.0012(0)	0.24(0.02)	10.18(0.44)	5.93(0.32)	98.22(1.46)	0.31(0)	0.29(0.03)	2.49(0.07)	8.63(1.1)	19.92(0.08)	88.09(2.82)
Kagoshima	18.86(0.32)	68.12(2.12)	0.0017(0)	0.25(0.02)	10.08(0.13)	5.63(0.37)	97.42(0.72)	0.29(0.01)	0.29(0.02)	3.89(0.11)	13.17(1.27)	36.17(0.52)	89.25(6.56)
Okinawa	23.28(0.22)	72.39(2.08)	0.0014(0)	0.16(0.01)	5.58(0.44)	4.79(0.41)	97.36(1.11)	0.35(0.01)	0.28(0.02)	2.62(0.23)	7.85(0.87)	19.78(0.01)	86.45(2.78)

CPI: consumer price index; EPI: Economic power index; AC: air conditioning prevalence.

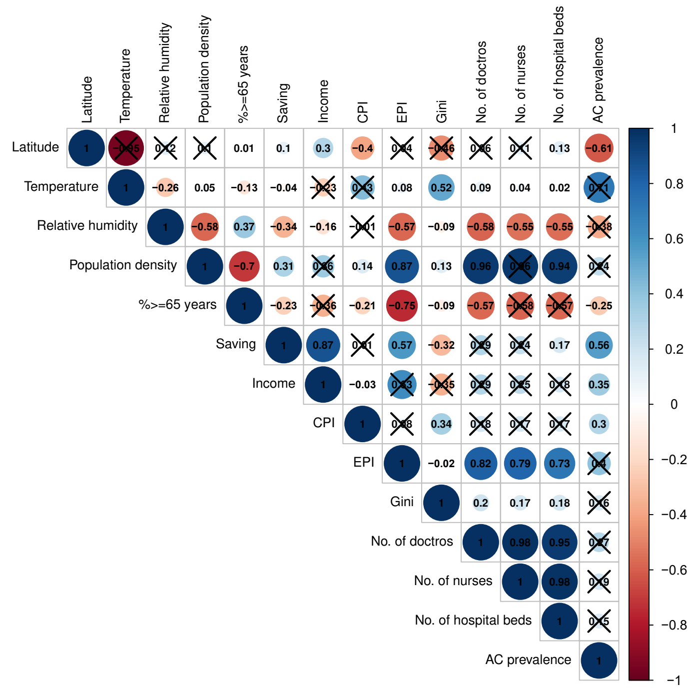

Figure S2. Correlations between the indicators.

Blue: positively associated; red: negatively associated; Cross: $p>0.05$.

RH: relative humidity; CPI: consumer price index; EPI: economic power index; AC: air conditioning prevalence

Figure S3. Peak-to-trough ratio (PTR) with 95% confidence intervals (95%CI) for each single year from 2000 to 2015 for all-cause (top), circulatory (middle), and respiratory (bottom) mortality before (black) and after adjustments for just influenza like illness (blue), just temperature (green), and both (red)

Note: The year of 1999 was excluded from our yearly analyses, as ILI data was not available until April 1999.

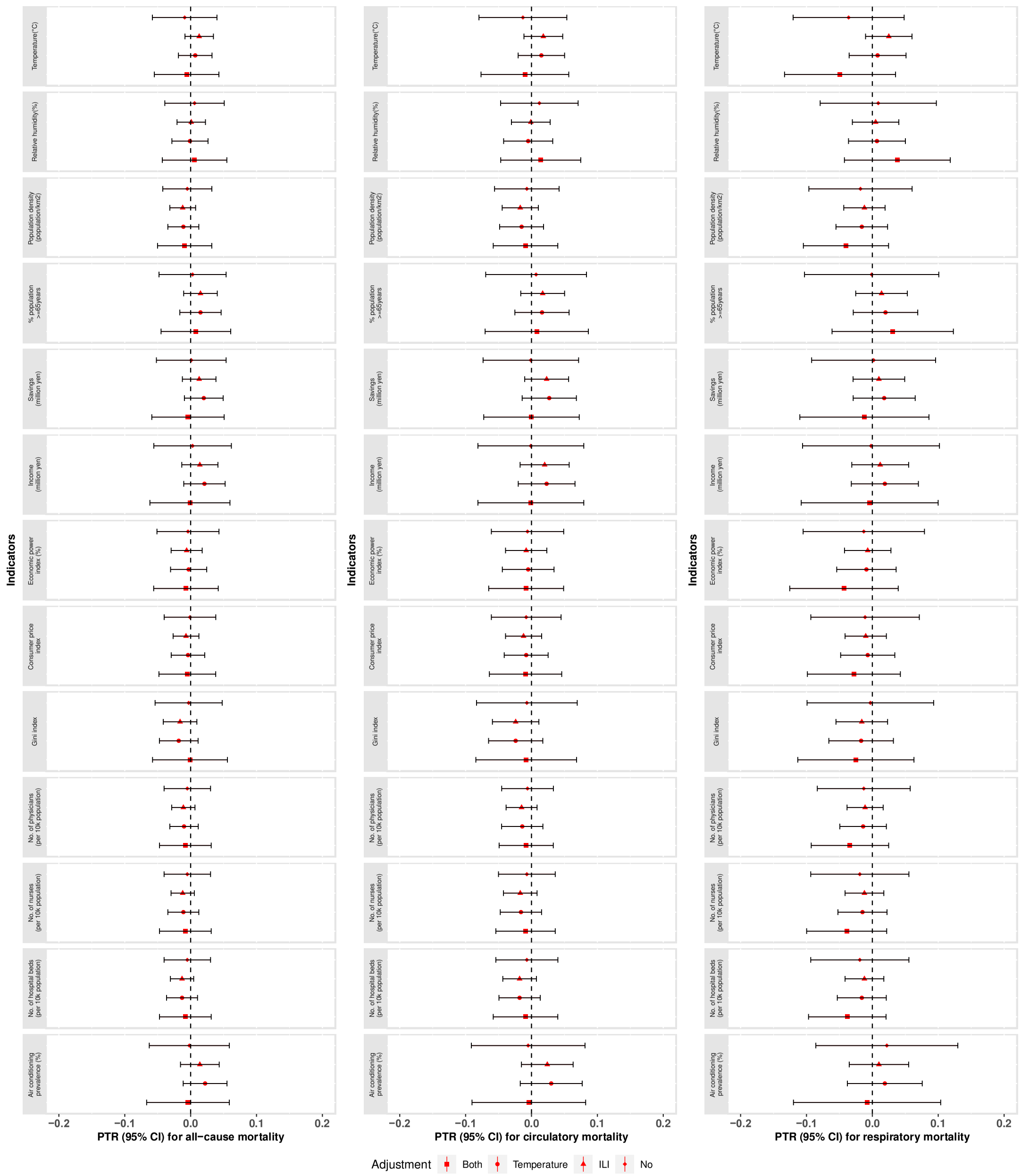

Figure S4. Associations between each indicator and PTR before and after adjusting for influenza like illness (ILI) and temperature

Coefficient and 95% confidence intervals were obtained from liner mixed effect models adjusting for latitude and longitude, except for when we investigated averaged annual mean temperature as the indicator, due to their high correlation. Results are expressed as log (PTR) change for standard deviation increase in each indicator.

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Description of models

- Seasonality assessment without and with adjustments for temperature and/or influenza like illness

We applied a generalized linear model with a quasi-Poisson family to assess seasonality of mortality in each prefecture.

$$\boldsymbol{Y_t \sim Quasi-Poisson(\mu_t)}$$

Main model (without any adjustment for temperature and ILI)

$\log(\mu_t) = \beta_0 + cs(doy, 4) + \lambda Strata_t$

Adjusting for temperature

$\log(\mu_t) = \beta_0 + cs(doy, 4) + \lambda Strata_t + \beta Temp_{t,l}$

Adjusting for ILI

$\log(\mu_t) = \beta_0 + cs(doy, 4) + \lambda Strata_t + ns(ILI_t, 3)$

Adjusting for both temperature and ILI

$\log(\mu_t) = \beta_0 + cs(doy, 4) + \lambda Strata_t + \beta Temp_{t,l} + ns(ILI_t, 3)$

t: the day of the observation;
Yt: the observed daily numbers of mortality on day *t*;
β_0: the intercept;
doy: day of year, which was fitted using cyclic cubic spline with 4 degrees of freedom (*df*);
ILI_t: the daily numbers of ILI on day t, which was controlled using natural cubic spline with 3 *df*;
$Stratat$: strata defined by year, day of week, and their interaction to control for the long-term trend and the effect of day of week, and λ is the vector of coefficients;
$Tempt$,*l*: a matrix obtained by using cross basis function to temperature; *l* is the lag days, and β is the vector of coefficients. (For the cross-basis function, a natural cubic B-spline basis with three internal knots at the 25th, 50th, and 75th percentiles of temperature distribution was used for exposure-response association, and another natural cubic B-spline basis with 3 *df* with extended lag up to 21 days was used for the lag-response association.)

- Modification of seasonal variation in mortality by prefecture-specific indicators

We applied linear mixed effects models (LMEMs) to investigate associations of PTR with each prefecture-specific indicator separately. We fitted LMEMs with random intercepts for prefectures and the inverse of squared SE as weight. The longitude and latitude for the capital city of each prefecture were included to reduce spatial correlation, except for when we investigated annual mean temperature as the indicator, due to their high correlation.

$$\boldsymbol{\beta_i = \alpha + \gamma Z_i + \eta + \nu_i}$$

β_i is the estimated coefficient for seasonality (i.e., log(PTR)) in prefecture i
Z_i is the prefecture-specific indicator for prefecture i (e.g., latitudes, longitudes, and averaged annual mean temperature)
α and γ are estimated using least squares regression with inverse-variance weights.
ν_i is the variation within prefecture i, with the variance as $\sigma^2_{\nu_i}$
η represents the heterogeneity among prefectures with a variance of σ^2_η estimated using the restricted maximum likelihood approach.

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Model Checking and sensitivity analysis

We used scatter plot of deviance residuals vs time and partial autocorrelation function plot of the deviance residuals to check the models. In addition, sensitivity analysis was conducted to check the robustness of our estimates.
We used the largest prefecture (i.e., Tokyo) for model evaluation, as the statistical uncertainty for the estimates was small.

- Scatter plot of deviance residuals vs time

In general, the plot shows an even band of points over the time, although we observed a few spikes, for example, in 1999. This pattern did not change significantly when we use more flexible modellings for seasonality, temperature, and influenza.

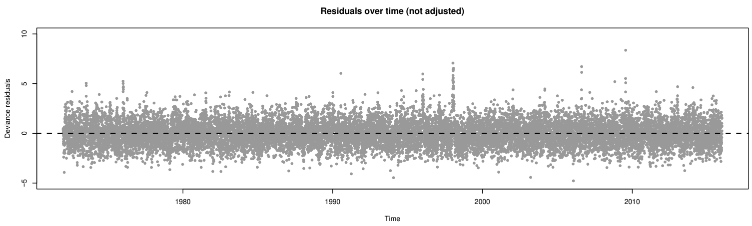

Figure S5. Deviance residuals over time from the analysis in Tokyo (without adjustment for temperature and/or influenza)

- Partial autocorrelation function (PACF) plot of the deviance residuals

PACF shows a slow decay and a high degree of autocorrelation around a 1-week lag. This pattern remained when we included temperature and/or ILI in the model. In order to reduce the autocorrelation, we tried more flexible functions for seasonality by increasing the degree of freedom, and then we added lagged deviance residuals to the model in several different ways. For example, 1-day lagged deviance residuals, 1- to 6-day lagged deviance residual, and a moving average of 6 days lagged deviance residuals, respectively. The autocorrelation remained without much reduction after many attempts, but the coefficient and its standard error from cyclic spline functions for seasonality changed very little (Table S4).

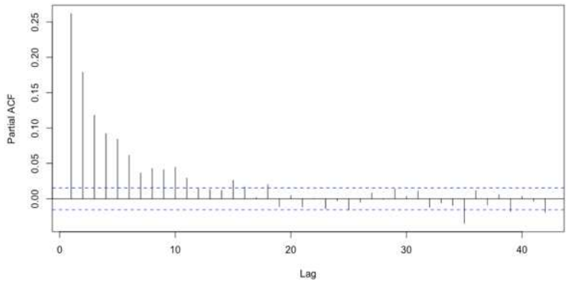

Figure S6. Partial autocorrelation function plot of the deviance residuals from the analysis in Tokyo (without adjustment for temperature and/or influenza)

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Table S4. Seasonality estimates for Tokyo without adjusting for temperature and/or influenza like illness

Models	Peak-to-Trough (95% confidence interval)
Main model	1.254 (1.249, 1.259)
Model 1	1.249 (1.237, 1.255)
Model 2	1.244 (1.237, 1.252)
Model 3	1.253 (1.249, 1.258)
Model 4	1.253 (1.248, 1.257)
Model 5	1.252 (1.248, 1.257)
Model 6	1.250 (1.247, 1.254)

Main model: $\log(\mu_t) = \beta_0 + cs(day - of - year, 4) + \lambda Strata_t$

($Stratat$: strata defined by year, day of week, and their interaction to control for long-term trend and effect of day of week)

Model 1: $\log(\mu_t) = \beta_0 + cs(day - of - year, 5) + \lambda Strata_t$

Model 2: $\log(\mu_t) = \beta_0 + cs(day - of - year, 6) + \lambda Strata_t$

Model 3: $\log(\mu_t) = \beta_0 + cs(day - of - year, 4) + \lambda Strata_t + Lag(residuals(main\ model), 1)$

Model 4: $\log(\mu_t) = \beta_0 + cs(day - of - year, 4) + \lambda Strata_t + Lag(residuals(main\ model), 1) +$
$Lag(residuals(main\ model), 2) + Lag(residuals(main\ model), 3)$

Model 5: $\log(\mu_t) = \beta_0 + cs(day - of - year, 4) + \lambda Strata_t + Lag(residuals(main\ model), 1) +$
$Lag(residuals(main\ model), 2) + Lag(residuals(main\ model), 3) + Lag(residuals(main\ model), 4) +$
$Lag(residuals(main\ model), 5) + Lag(residuals(main\ model), 6)$

Model 6: $\log(\mu_t) = \beta_0 + cs(day - of - year, 4) + \lambda Strata_t + runmean(residuals(main\ model), 6)$

- The fit of the model to the daily death counts over time

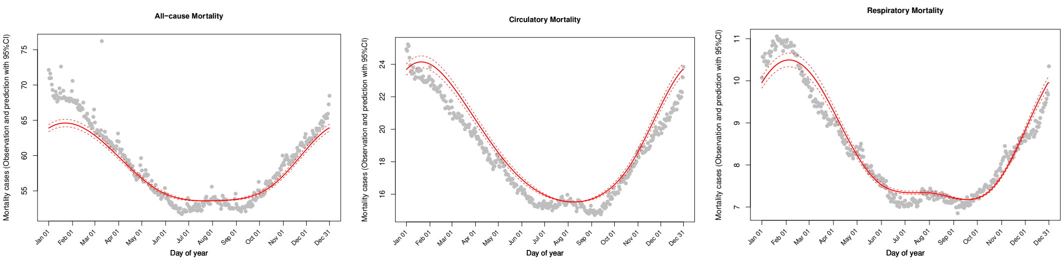

Figure S7. Daily mean number of observed aal-cause, circulatory, and respiratory mortality in Japan averaged from 47 prefectures over the study period and estimated number of daily circulatory mortality from time series regression models (Main model)

Grey dot: daily mean number of observed mortality cases averaged from 47 prefectures over the study period;
Red: pooled estimates with 95% confidence intervals obtained from prefecture-specific estimates from models without temperature adjustment

Figure S7 suggests that our models fitted seasonality of circulatory mortality better and may underestimate the seasonal variation in all-cause and respiratory mortality. The discrepancy between observed and fitted values may be explained by the risk of temperature, infectious disease, and other factors (e.g., human behaviour).