ORIGINAL ARTICLE: ENVIRONMENT AND EPIDEMIOLOGY

Climate change is associated with male:female ratios of fetal deaths and newborn infants in Japan

Misao Fukuda, M.D., Ph.D.,[a] Kiyomi Fukuda, M.D.,[a] Takashi Shimizu, M.D., Ph.D.,[b] Miho Nobunaga, M.D., Ph.D.,[b] Linn Salto Mamsen, M.Sc.,[c] and Claus Yding Andersen, M.Sc., D.M.Sc.[c]

[a] M&K Health Institute, Ako; [b] Shimizu Women's Clinic, Minamiguchi, Takarazuka, Hyogo, Japan; and [c] Laboratory of Reproductive Biology, Juliane Marie Center for Children, Women and Reproduction, Rigshospitalet, University Hospital of Copenhagen, Copenhagen, Denmark

Objective: To evaluate whether climate change is associated with male:female ratios (sex ratios) of fetal deaths and births in Japan.
Design: A population-based cohort study.
Setting: Not applicable.
Patient(s): Newborn infants and fetuses spontaneously aborted after 12 weeks of gestation.
Intervention(s): None.
Main Outcome Measure(s): Yearly sex ratios of fetal deaths and newborn infants and monthly fetal death rates and sex ratios of newborn infants.
Result(s): A statistically significant positive association was found between yearly temperature differences and sex ratios of fetal deaths; a statistically significant negative association was found between temperature differences and sex ratios of newborn infants from 1968 to 2012, and between sex ratios of births and of fetal deaths. The sex ratios of fetal deaths have been increasing steadily along with temperature differences, whereas the sex ratios of newborn infants have been decreasing since the 1970s. Two climate extremes, a very hot summer in 2010 and a very cold winter in January 2011, showed not only statistically significant declines in sex ratios of newborn infants 9 months later in June 2011 and October 2011 but also statistically significant increases of fetal death rates immediately, in September 2010 and January 2011.
Conclusion(s): The recent temperature fluctuations in Japan seem to be linked to a lower male:female sex ratio of newborn infants, partly via increased male fetal deaths. Male concepti seem to be especially vulnerable to external stress factors, including climate changes. (Fertil Steril® 2014;■:■–■. ©2014 by American Society for Reproductive Medicine.)
Key Words: Climate change, climate extreme, sex ratio of fetal deaths, sex ratio of newborn infants, temperature difference

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The ratio of male to female newborn infants is considered to be rather constant around the world, with a small surplus of boys. However, subtle changes to this sex ratio have been reported from a number of countries, including Denmark (1), England and Wales (2), Canada (3), the Netherlands (4), Germany (5), the United States (6), Sweden, Norway, and Finland (7), and Japan (8). The mechanisms that result in a varying male:female sex ratio subsequent to various stress conditions are unknown, but the change likely reflects multiple factors, including chronic exposure to environmental toxic agents such as tobacco smoke (9), as well as natural catastrophes such as earthquakes (10–12).

It has been reported that male births decline with increasing geographical latitude in Europe and Asia (13, 14). Moreover, reports indicate that the sex ratio (this term is used throughout the current article to indicate male:female ratio) of newborn infants is associated with seasonality (15–17). It has also been reported that years with a high average temperature correlated with a higher birth sex ratio (18). These studies suggest that climate temperature conditions are associated with the sex ratio of newborns.

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Reprint requests: Misao Fukuda, M.D., Ph.D., M&K Health Institute, 30-9 Kariya, Ako, Hyogo 678-0239, Japan (E-mail: web@fukuda8767.com).

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An interesting question is whether global warming, which has happened at an average rate of 0.69°C per 100 years during the past century, is having any impact on the sex ratio of newborn infants. It has recently been reported that no significant time-dependent association was found between yearly mean temperatures and sex ratios of infants born from 1865 to 2003 in Finland (19) or from 1876 to 2009 in New Zealand (20). In Japan, climate warming has been substantial, with an average temperature increase of 1.15°C per 100 years.

Furthermore, climate changes and temperature extremes apparently occur more frequently than previously. Thus, we tested a possible association between climate changes, spontaneous fetal deaths, and sex ratios of births in 2 ways. First, to examine the relationship of climate warming, spontaneous fetal deaths, and sex ratios of births, we compared yearly mean temperature differences or anomalies (the sum of monthly mean temperature minus the mean temperature during the previous 30 years for the same month/12) to male:female ratios of spontaneous fetal deaths after 12 weeks of gestation and male:female ratios of newborn infants from 1968 to 2012. Second, to determine the relationship of climate extremes, spontaneous fetal deaths, and sex ratios of births, we compared monthly mean temperature differences (monthly mean temperature minus the mean temperature during the previous 30 years for the same month) to fetal death rates and male:female ratios of births in recent years (2010–2012).

MATERIALS AND METHODS

Institutional review board approvals were obtained from M&K Health Institute and Shimizu Women's Clinic. Yearly or monthly mean temperature differences from 1968 to 2012 in Japan were obtained from the Japan Meteorological Agency (yearly: http://www.data.jma.go.jp/cpdinfo/temp/list/an_jpn.html; monthly: http://www.data.jma.go.jp/cpdinfo/temp/list/mon_jpn.html). Yearly and monthly sex ratios of fetal deaths and newborn infants in Japan from 1968 to 2012 were obtained from Vital Statistics of Japan (21).

Climate Warming

We assessed whether the following 3 variables are linked:

1. Yearly mean temperature differences in Japan from 1968 to 2012 were the exposure of interest. The mean temperature was 14.1°C, which was drawn from the data in 15 places ranging from north (Nemuro, Hokkaido: 6.3°C) to south (Ishigakijima, Okinawa: 24.3°C) in Japan during 1981–2010. Urbanized cities such as Tokyo (16.3°C) and Osaka (16.9°C) were excluded.
2. Yearly male:female ratios of spontaneous fetal deaths after 12 weeks of gestation from 1968 to 2012 were the outcome of interest.
3. Yearly male:female ratios of newborn infants in Japan from 1968 to 2012 were the outcome of interest. The sex ratio at birth was expressed as the ratio of the number of male to the number of female newborn infants.

Recent Climate Extremes

In order to clarify the long-term effect of yearly temperature differences on sex ratios of fetal deaths and newborn infants, we assessed whether the 3 previously mentioned variables are associated in 2 recent climate extremes (the hottest summer: 2010; the coldest January: 2011) observed prior to the Tohoku earthquake in Japan (March 11, 2011). We assessed whether the climate extremes affect a fetal death rate immediately and/or a decline in sex ratio of births around 9 months later. We also assessed the data on Miyagi Prefecture, Japan, which was close to the epicenter of the earthquake (total number killed: 10,836), to clarify effects of the earthquake occurring soon after these 2 climate extremes on fetal death rate and/or sex ratio of births.

Data Analysis

Statistical analyses were performed using Microsoft Excel Statistics 2012 for Windows. Pearson correlation coefficients (r) were used to evaluate whether yearly mean temperature differences were associated with either male:female ratios of spontaneous fetal deaths or male:female ratios of births. The same measure was used to evaluate whether monthly mean temperature differences were associated with spontaneous fetal death rates or male:female ratios of births.

The sex ratios of fetal deaths and births in years with positive temperature differences and in years with negative temperature differences from 1968 to 2012 were compared using an unpaired t test. The sex ratios of fetal deaths between 16 and 19 weeks of gestation, and the overall fetal death rates, for 1968 were compared to those for 2012. Values were expressed as mean ± SD (standard deviation). The chi-square test or Fisher's exact test was utilized to analyze categorical frequency data. Prevalence ratios (PRs) and 95% confidence intervals (95% CI) of spontaneous fetal death rates or male:female ratios of births from a certain month were evaluated as compared to the combined data of the corresponding month from only 3 total months previously, the same month and one month within the previous 12 months, therefore data of 4 months were accumulated. A P value of $<.05$ was considered statistically significant.

RESULTS

Climate Warming

A statistically significant positive association was found between yearly mean temperature differences (the exposure of interest) and sex ratios of fetal deaths (the outcome of interest) ($r = 0.670$, $P<.0001$); a statistically significant negative association was found between temperature differences (the exposure of interest) and sex ratios of births (the outcome of interest) from 1968 to 2012 ($r = -0.518$, $P=.0002$). In addition, a statistically significant negative association was found between sex ratios of births and sex ratios of fetal deaths from 1968 to 2012 ($r = -0.767$, $P<.0001$). As previously described, the interval between assessment of temperature differences and sex ratios of births is 9 months; therefore, we also computed the Pearson correlation between the sex ratios of births from 1968 to 2012 and the