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Births and male:female birth ratio in Scandinavia and the United Kingdom after the Windscale fire of October 1957

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Abstract.
AIMS: The Windscale (UK) fire of 1957 carried radioactive fallout according to the then prevailing wind patterns, in a North-Easterly direction across the Nordic countries, toward Norway. The male:female ratio at birth (M/F) is known to be increased after parental exposure to ionising radiation due to foetal losses that affect female more than male pregnancies. This study was carried out in order to ascertain whether the Windscale fire had any effects on M/F and birth rates in the United Kingdom and Scandinavia.
METHODS: Annual live births by gender were obtained from a World Health Organization dataset. The null hypothesis was that there were no significant changes in M/F or in births in temporal association with the 1957 Windscale event in abovementioned countries.
RESULTS: There were no significant effects on the UK and most of Scandinavia but there was a significant rise in M/F for Norway and Finland with an aggregate deficit of around 4000 births in each country.
CONCLUSIONS: A recent study suggests that the plume from the reactor extended further east than previously believed. This study confirms that contamination from the Windscale fire had a negligible impact on the UK (as measured by birth effects) but had a significant impact on births in Norway and Sweden.

Keywords: Great Britain/epidemiology, Scandinavia, sex Ratio, birth Rate/*trends, infant, newborn, radiation, Ionizing

1. Introduction

The Windscale fire of 10 October 1957 was the worst nuclear accident in the history of the United Kingdom. In severity, it was ranked at level 5 on the 7-point International Nuclear Event Scale (the Chernobyl disaster of April 1986 and the Fukushima Daiichi nuclear disaster of March 2011 were rated at level 7) [1].

The accident occurred when the core of one the nuclear reactors at the Windscale (now Sellafield, Cumbria) plant caught fire and burned for three days, releasing substantial amounts of radionuclides into the surrounding area. Winds also carried radioactive fallout according to the then prevailing wind patterns, in a North-Easterly direction across the Nordic countries, toward Norway [2].

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M/F is known to be increased after parental exposure to ionising radiation [3]. This has been most clearly shown in relation to the Chernobyl disaster of 1988, in association with a decline in birth rate [4].

Secular and geographical (latitude) trends in both the British Isles and the Nordic countries have already been published [5,6].

This study was carried out in order to ascertain whether the Windscale fire had any effects on M/F and birth rates in the United Kingdom and Scandinavia.

2. Methods

2.1. Data

Annual live births by gender were obtained from a World Health Organization dataset.

2.2. Statistics

Data was analysed for the periods 1953–1968 in five year intervals (1953–57, 1958–63 and 1964–68) for the following regions in the United Kingdom: Northern Ireland, Scotland, Ireland and England and Wales. For Scandinavia, the following countries were analysed: Iceland, Norway, Sweden, Finland and Denmark. The four years prior to the event (1953–57) were compared with the two four year periods after the event: 1958–63 and 1964–68. Short periods were used as it is known that M/F exhibits broad secular shifts, rendering extrapolation/s difficult [7].

Excel was used for data entry, overall analysis and charting. The quadratic equations of Fleiss were used for exact calculation of 95% confidence intervals for ratios [8]. Linear regression was carried out in order to attempt to extrapolate expected births in the presence of outlier (observed) values.

Chi tests for trend were used for annual male and female births. These were performed using the Bio-Med-Stat Excel add-in for contingency tables. This add-in is based on the original work by Cochran and Armitage (Dr. Peter Slezák, Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, personal communication) [9, 10].

A p value ≤ 0.05 was taken to represent a statistically significant result.

The null hypothesis was that there were no significant changes in M/F in temporal association with the 1957 Windscale event in abovementioned countries.

3. Results

Results for the UK are shown in Table 1. There were no significant effects on M/F. There were no significant shifts in total live births for any of the regions involved after 1957.

Results for Scandinavia are shown in Table 2. There was a significant decline in M/F for Denmark and a significant rise in M/F for Norway (1953–7 vs. 1963–67, $x = 4.2$, $p = 0.039$) and Finland (1953–7 vs. 1958–62, $x = 4.0$, $p = 0.047$).

For Norway, for the period 1953–1967, this rising trend in M/F was significant (x trend 4.7, $p = 0.03$). The annual percentage change in live births, averaged over 5 year periods was 0.172 (1953–57), −0.2548 (1958–62) and 1.421 (1963–67). Table 3 shows the percentage increment in male and female births in Norway for the period 1953–67. This was used to extrapolate male and female live births (expected) for

Table 1
M/F in 5 year intervals for the United Kingdom, 1953–58 (Windscale fire October 1957)

Northern Ireland	1953–57	1958–62	1963–67
M	75531	81400	87141
F	70818	76179	81151
T	146349	157579	168292
UCI	0.5187	0.5190	0.5202
M/F	0.5161	0.5166	0.5178
LCI	0.5135	0.5141	0.5154
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	0.1		0.9
p	0.8		0.3
Scotland	1953–57	1958–62	1963–67
M	241094	259989	257801
F	227963	245538	242662
T	469057	505527	500463
UCI	0.5154	0.5157	0.5165
M/F	0.5140	0.5143	0.5151
LCI	0.5126	0.5129	0.5137
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	0.1		1.2
p	0.8		0.3
England & Wales	1953–57	1958–62	1963–67
M	1774344	2020184	2197901
F	1675206	1904054	2076838
T	3449550	3924238	4274739
UCI	0.5149	0.5153	0.5146
M/F	0.5144	0.5148	0.5142
LCI	0.5138	0.5143	0.5137
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	1.3		0.3
p	0.2		0.6
Ireland	1953–57	1958–62	1963–67
M	158403	154661	161498
F	150293	147379	152867
T	308696	302040	314365
UCI	0.5149	0.5138	0.5155
M/F	0.5131	0.5121	0.5137
LCI	0.5114	0.5103	0.5120
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	0.7		0.2
p	0.4		0.6

1958–67. Expected births (based on a percentage increment of 0.172/annum) and observed totals (actual) show that for the period 1958–62, there was a deficit of over 4000 births. There was an overall decline in total births up to 1963, followed by a rise (Fig. 1).

Table 2
M/F in 5 year intervals for Scandinavia, 1953–58 (Windscale fire October 1957)

Iceland	1953–57	1958–62	1963–67
M	11574	12166	11940
F	10794	11502	11484
T	22368	23668	23424
UCI	0.5240	0.5204	0.5162
M/F	0.5174	0.5140	0.5097
LCI	0.5109	0.5076	0.5033
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	0.5		2.7
p	0.5		0.1
Norway	1953–57	1958–62	1963–67
M	162416	160991	169657
F	154094	151688	159320
T	316510	312679	328977
UCI	0.5149	0.5166	0.5174
M/F	0.5131	0.5149	0.5157
LCI	0.5114	0.5131	0.5140
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	1.9		4.2
p	0.2		0.039
Sweden	1953–57	1958–62	1963–67
M	277135	270074	310537
F	260538	254175	292550
T	537673	524249	603087
UCI	0.5168	0.5165	0.5162
M/F	0.5154	0.5152	0.5149
LCI	0.5141	0.5138	0.5137
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	0.1		0.3
p	0.8		0.6
Finland	1953–57	1958–62	1963–67
M	228624	210885	202383
F	217708	199095	193167
T	446332	409980	395550
UCI	0.5137	0.5159	0.5132
M/F	0.5122	0.5144	0.5116
LCI	0.5108	0.5128	0.5101
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	4.0		0.3
p	0.047		0.6

For Finland, for the period 1953–1967, the rising trend in M/F was not significant (x trend 0.4, $p = 0.5$). Table 4 extrapolates births for Finland as was done for Norway. The expected and observed totals (actual) show that for this country, for the period 1958–62, there was also a deficit of over 4000 births.

Table 2
(*Continued*)

Iceland	1953–57	1958–62	1963–67
Denmark	1953–57	1958–62	1963–67
M	197910	194425	216646
F	185550	184508	204661
T	383460	378933	421307
UCI	0.5177	0.5147	0.5157
M/F	0.5161	0.5131	0.5142
LCI	0.5145	0.5115	0.5127
	1953–7 vs. 1958–62		1953–7 vs. 1963–67
x	7.0		2.9
p	0.008		0.1

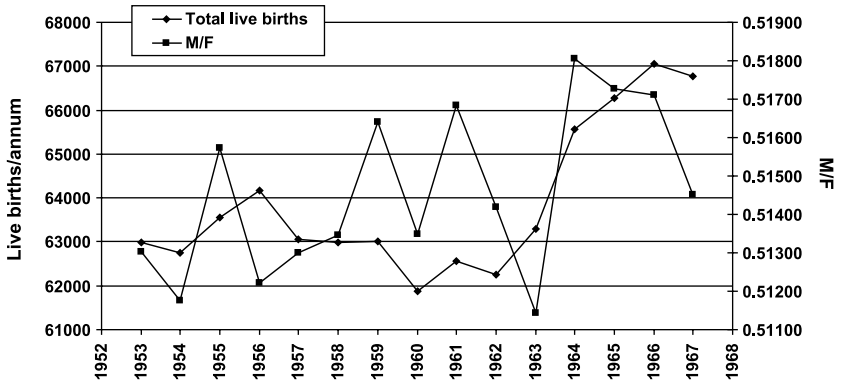

Fig. 1. Annual live births and M/F for Norway, 1953–1967.

There was an overall decline in total births from1953 to 1967 (Fig. 2). The annual percentage change in live births, averaged over 5 year periods was −1.60 (1953–57), −1.258 (1958–62) and −1.033 (1963–67). There was a sharper decline in 1958 for total births and an inflection point in 1962, where the rate of decline decreases. Simple linear regression for the period 1953–62, excluding 1958, yielded the following equation (adjusted r square 0.96, F = 173.6, $p < 0.0001$): births = 2413128.7+(−1188.8× year). Separate regressions were carried out on both genders in order to extrapolate a value for 1958 for both genders, arriving at a total deficit of 4321 births for 1958 (Table 5).

For both countries, the effect/s appear to be ameliorated in the second five year period after the event.

4. Discussion

Iodine-131, caesium-137 and polonium-210 were the dominant contaminants released in the fire and there is evidence to support the hypothesis that the plume from the reactor extended further east than believed in previous assessments [11].

Table 3
Observed and expected live births in Norway for the period 1958–67, and estimated deficit for 1958–62

	5 year mean birth live % increment (1953–7)	Expected 1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	Expected 1958–62	Observed 1958–62	Deficit 1958–62	Expected 1958–67	Observed 1958–67
M	0.171872	32408	32463	32519	32575	32631	32687	32743	32800	32856	32912	162596	160991	1605	326594	330648
F	0.171872	30764	30817	30870	30923	30976	31029	31082	31136	31189	31243	154349	151688	2661	310028	311008
													Total	4266		

Table 4
Observed and expected live births in Finland for the period 1958–67, and estimated deficit for 1958–62

	5 year mean birth live % increment (1953–7)	Expected 1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	Expected 1958–62	Observed 1958–62	Deficit 1958–62	Expected 1958–67	Observed 1958–67
M	−1.59731	43932	43230	42540	41860	41191	40534	39886	39249	38622	38005	212753	210885	1868	409049	413268
F	−1.59731	41664	40998	40343	39699	39065	38441	37827	37223	36628	36043	201769	199095	2674	387930	392262
													Total	4542		

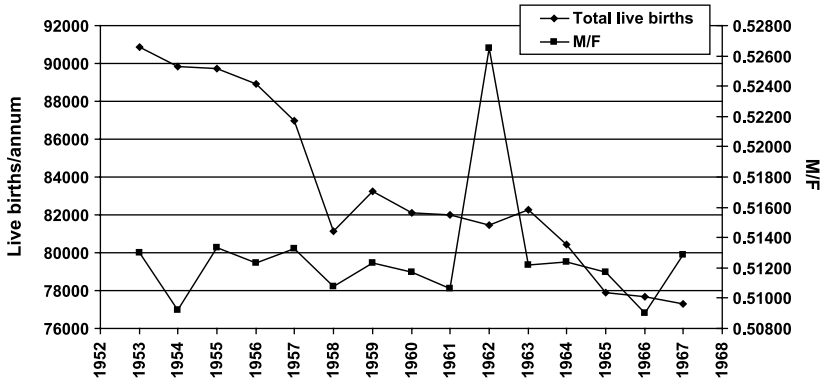

Fig. 2. Annual live births and M/F for Finland, 1953–1967.

Table 5
Observed births in Finland, 1957–1959 and expected (extrapolated) value for 1958

1953–62	R^2	F	p	Equation	Expected	Observed	Difference
Males	0.88	51.2	0.0002	male births = 1115591.4+(−547.3× year)	43925	41447	2478
Females	0.97	208.3	<0.0001	female births = 1297537.3+(−641.5× year)	41544	39701	1843
						Total Deficit	4321

A recent study of workers directly involved in the cleanup operation found no significant long term health effects from their involvement [12]. Moreover, analysis of the sedimentary layers of a lake on the northeast coast of Ireland found no evidence of any enhancement in radioisotope concentrations, over and above global fallout, in strata dated to 1957 [13]. This study confirms that contamination from the Windscale fire had a negligible impact on the United Kingdom, at least as indirectly measured by the influence on total births and M/F. However, a few studies continue to raise questions with regard to the effect on this region, such as a striking cluster of Down's syndrome babies [14].

Conversely, this study shows that Scandinavia was affected, with an increase in M/F and a drop in births that are temporally related to the Windscale fire. M/F has been proposed as a unique indicator with regard to radiation exposure since maternal exposure results in differing outcomes to paternal exposure [15]. Irradiated men sire an excess of males [16], while irradiated women give birth to an excess of females [17]. However, when both genders within a population are approximately equally exposed, an overall increase in M/F is produced [3].

This is attributed to the theory that if an X-linked recessive lethal gene is induced in a mother's germ cell line by ionising radiation, it would have no effect on a heterozygous daughter but would be lethal if passed to a male zygote. Furthermore, X-linked recessive lethal mutations in mothers would shift M/F to favour female offspring. X-linked dominant lethal mutations in mothers would be equally lethal to both genders [18].

X-linked dominant mutations induced in fathers would suppress only female offspring. Recessive X-linked lethal mutations in fathers would not influence M/F as sons do not receive the paternal X-chromosome and daughters carry a second, protective X-chromosome from their mother [18].

In the setting of radiation exposure, M/F is therefore altered through increased foetal mortality. It is speculated that the skew toward higher female mortality may be due to the fact that the X chromosome

contains more genetic material and is larger, and hence, may be physically more easily hit by ionising radiation. Another possibility is that ova and sperm afford their genetic material different levels of protection [3].

The declining trend in M/F in Denmark during the period studied is not related to a decline in births and constitutes part of the overall secular trend already described for this country over the period 1950 to 2009 [5].

These results support the contention that the Windscale repercussions were more severe than previously thought, with a loss of around 8000 pregnancies in Norway and Finland.

Indeed, a recent study that re-examined winds patterns and vegetation in 1957 with computer models estimated that the amount of radioactive fallout may have been double that initially proposed [11].

It will be interesting to observe whether the level 7 Fukushima Daiichi nuclear event of 2011 will have similar ramifications.

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