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Do short birth intervals have long-term implications for parental health? Results from analyses of complete cohort Norwegian register data

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ABSTRACT

Background Short and very long interbirth intervals are associated with worse perinatal, infant and immediate maternal outcomes. Accumulated physiological, mental, social and economic stresses arising from raising children close in age may also mean that interbirth intervals have longer term implications for the health of mothers and fathers, but few previous studies have investigated this.

Methods Discrete-time hazards models were estimated to analyse associations between interbirth intervals and mortality risks for the period 1980–2008 in complete cohorts of Norwegian men and women born during 1935–1968 who had had two to four children. Associations between interbirth intervals and use of medication during 2004–2008 were also analysed using ordinary least-squares regression. Covariates included age, year, education, age at first birth, parity and change in coparent since the previous birth.

Results Mothers and fathers of two to three children with intervals between singleton births of less than 18 months, and mothers of twins, had raised mortality risks in midlife and early old age relative to parents with interbirth intervals of 30–41 months. For parents with three or four children, longer average interbirth intervals were associated with lower mortality. Short intervals between first and second births were also positively associated with medication use. Very long intervals were not associated with raised mortality or medication use when change of coparent since the previous birth was controlled.

Conclusions Closely spaced and multiple births may have adverse long-term implications for parental health. Delayed entry to parenthood and increased use of fertility treatments mean that both are increasing, making this a public health issue which needs further investigation.

INTRODUCTION

In poorer and richer countries, adverse birth outcomes are associated with short and very long birth intervals,[1–8] and the WHO recommends an interval of at least 24 months from a live birth to the next pregnancy.[9] Interpregnancy or interbirth intervals have additionally been associated with short-term maternal outcomes, again with some indication of a U-shaped association.[10–12] The causal mechanisms underlying these associations are hypothesised to include pathways through maternal nutrition, particularly folate status.[12–15] Lack of sufficient time to return to the normal prepregnancy metabolic state before the next pregnancy may also initiate processes with longer term implications; for example, a prospective US study found that risks of maternal obesity increased with each interpregnancy interval of <12 months.[16] The physical, emotional and economic strains involved in meeting the needs of two or more children close in age may also lead to stresses relevant to health. Mothers of twins, for example, suffer from higher rates of postnatal depression than mothers of singletons[17–19] and multiple births are associated with higher risks of subsequent divorce.[20] Similar, if less marked, effects might apply to parents of closely spaced singleton children. Very long gaps between births may result in maternal physiological regression such that risks for mothers (and infants) revert to those associated with primiparous women.[6] Unusually, widely spaced families may also result in social stress. Apart from these hypothesised linkages, selection effects may be relevant. Closely spaced childbearing may reflect less breast feeding and less efficient use of contraception and be associated with other health behaviours and socioeconomic status. Very long intervals may be a consequence of poor parental health status, impaired fecundity or partnership breakdown,[21–24] all of which have implications for later health.

Given the importance of accumulated life course effects on health in later life,[25] stresses associated with short interbirth intervals may have longer term health implications for mothers and fathers. In this study, we investigate this using Norwegian Population Register data for complete cohorts born during 1935–1968.

To the best of our knowledge, only two previous studies have investigated this, both of which used a dichotomised indicator of whether parents had experienced any interbirth interval of less than 18 months and relied on some retrospective reporting of fertility histories. The first used linked census and vital registration data for 1% of the population of England and Wales and found that among women born during 1911–1920, mothers of twins and those with any interbirth interval of less than 18 months had raised mortality risks at ages 50–89. In later born cohorts, mortality was raised among mothers of twins, but not among mothers of closely spaced singletons.[26] A later British study based on panel data for parents aged 50–83 found that experience of any interbirth interval of less than 18 months (including twins) was positively associated with poor self-rated health among women and with health limitations among women and men.[27]

In this study, we employ a detailed categorisation of interbirth intervals rather than a dichotomous

indicator in order to see whether longer term effects of birth interval lengths follow a U-shaped association similar to that reported for short-term maternal outcomes. We hypothesised that stresses associated with short interbirth intervals might be cumulative and investigate effects of experience of more than one short interval and average interval length, as well as examining parity-specific effects. We consider women and men as this may clarify the extent to which any associations reflect long-term physiological consequences for women or broader biosocial effects relevant to mothers and fathers.

METHODS

Data and measures

The Norwegian Central Population Register includes everyone who has ever lived in Norway since 1960, all of whom are assigned a personal identification number. Identification numbers of parents have been recorded at registration of births since 1964, and for those born earlier, parents were identified for children living in the parental household at the 1970 census (usual among those then younger than 18). Thus, parents are identified for almost all children born after 1953, and conversely, almost complete maternity and paternity histories can be assembled for women and men born after 1935.[28] Other registers using the same identification number include an Educational Database and, since 2004, the Norwegian Prescription Database.[29] This records all purchases of prescription medication (defined by Anatomical Therapeutic Code (ATC)) by all residents except those in healthcare institutions.

We analyse mortality at age 40 and over, when women have very largely completed their childbearing, for the period 1980–2008 and purchase of prescription medicine during the period 2004–2008. As the exposure of interest is birth interval length, those with only one child are excluded. To simplify the analysis, we also excluded the 5% of parents who had had five or more children.

Interbirth intervals

Birth interval length was grouped into seven categories denoting at one end of the distribution multiple births and at the other intervals of 90 or more months. The interval 30–41 months, which includes the WHO recommended minimum interval, was used as the reference category. For data protection reasons, only year of births was available for the analysis of medication purchase. For this analysis, we therefore categorised birth interval lengths in years, ranging from less than 1 (including multiple births) to seven or more.

Covariates

Our outcome variables include deaths observed during a 28-year period when mortality rates fell substantially and fertility changed. We therefore control for period of observation in the mortality models and age in all analyses. Fertility patterns are strongly associated with level of education and marital status, both of which are also associated with health,[23 28] we therefore also included these in all models. In a separate step, we added controls for age at first birth and total number of children born. Both are associated with later-life mortality[26 27 30 31] and are likely to be associated with birth interval lengths (eg, women who start childbearing at older ages may compress subsequent birth intervals[5 21]). Very long birth intervals may be associated with repartnering after partnership disruption, which is associated with later health and mortality.[23 24] In a final step, we therefore included an indicator of whether there had been a change of coparent over the birth interval.

STATISTICAL ANALYSIS

Mortality analysis

Discrete-time hazard models were estimated following standard procedures.[32] A series of 1-year observations was created, starting in January of the year the person turned 40 or, for those born during 1935–1939, from the beginning of 1980. The last observation was the year of death, the year of emigration or 2008, whichever came first. Owing to the fact that everyone included in the analysis was born in 1935 or later and the last possible year of observation is 2008, the oldest age considered is 73. In the period considered, fewer than 2% of men and 1% of women died before age 40, so those included constitute the vast majority of their respective birth cohorts.[33]

After excluding observations relating to absences abroad, sex-specific logistic models were estimated using the Proc Logistic procedure in the SAS software suite. All variables refer to the situation at the beginning of each 1-year observation period or are by definition constant.

Analysis of prescription drug purchase

Approaches to deriving morbidity indicators from medication data vary considerably.[34–37] We used the total number of different medicines purchased (defined as the first five ATC digits being different) and the total number of diseases inferred using Kuo *et al*'s[38] identification of 32 conditions treated by drugs uniquely prescribed for these conditions.

We estimated ordinary least-squares models for the total number of different drug purchases during 2004–2008, and for the number of different diseases inferred from these purchases, for women and men aged 40–69 years in 2004 and alive and in the country throughout 2004–2008.

RESULTS

Descriptive results

Table 1 shows the number of deaths and distribution of exposure time by variables used in the analysis; table 2 presents the distribution by sociodemographic characteristics and length of the first interbirth interval. Fifty-three per cent of the study population had two births, 35% three and 12% four. One per cent of parents had had a twin birth first; a further 10% had a first interbirth interval shorter than 18 months and 18% had intervals longer than 5 years. Intervals of less than 18 months between first and second singleton births were inversely related to the level of education and showed a U-shaped association with age at first birth. The association between birth interval lengths and overall parity is evident in the higher proportion of high parity parents with a short first interbirth interval. The well-established increase in twinning rates with maternal age is evident in the linear increase in twin first maternities with older age at first birth. There was a strong association between very long intervals and a change of coparent across the interval. Distributions for subsequent birth intervals (see online supplementary table S1) showed slightly higher proportions of multiple births, lower proportions of intervals of 0>18 months and higher proportions with very long intervals.

Model results

Table 3 shows estimates from the three previously described models of variation in mortality associated with the length of the first, second and third interbirth intervals. Relative to those with interbirth intervals of 30–41 months, results from model 3 show that first intervals between singleton births of less than 18 months were associated with higher mortality risks of 12–

Table 1 Number of deaths and distribution (%) of exposure time, men and women born during 1935–1968 and aged 40–73 years in 1980–2008 who had had two to four children

	Men		Women	
	Deaths	Per cent of exposure time	Deaths	Per cent of exposure time
Period				
1980–1984	1378	5.7	757	5.5
1985–1989	3180	10.6	1871	10.4
1990–1994	5151	15.5	3207	15.3
1995–1999	8212	20.2	5363	20.2
2000–2004	12 018	24.8	8321	25.0
2005–2008	13 348	23.2	9213	23.6
Age group				
40–44	4006	27.5	2717	28.0
45–49	6186	24.8	4084	24.5
50–54	7564	19.5	5060	19.2
55–59	8498	14.2	5802	14.1
60–64	8583	8.9	5529	8.9
65–69	6310	4.2	4087	4.3
70–73	2140	1.0	1453	1.1
Education (years)				
10	15 227	23.7	12 483	29.5
11–13	20 083	46.8	12 256	46.9
14–17	5838	20.3	3617	21.0
18+	2139	9.2	376	2.6
Marital status				
Never-married	882	2.6	447	2.6
Married	29 304	81.4	18 587	76.5
Widowed	1383	1.2	3036	4.5
Separated/divorced	11 718	14.8	6662	16.4
Number of children				
2	22 112	53.9	14 736	53.1
3	15 093	34.7	10 015	35.1
4	6082	11.4	3981	11.8
Age at first birth				
<20	1485	2.5	5187	13.6
20–22	9035	16.5	9932	30.8
23–25	13 225	28.3	7205	26.8
26–28	9910	25.0	3838	16.4
29–31	5381	14.9	1616	7.6
32–34	2455	7.4	661	3.1
35–37	1027	3.4	222	1.2
38+	769	2.1	71	0.4
Change of coparent birth 1–2				
No	40 132	93.8	26 160	93.0
Yes	3155	6.2	2572	7.0
Change of coparent birth 2–3				
No	19 234	42.5	12 918	44.0
Yes	1941	3.6	1978	2.9
Not applicable	22 112	53.9	14 736	53.1
Change of coparent birth 3–4				
No	5486	10.5	3685	11.1
Yes	596	0.9	296	0.8
Not applicable	37 205	88.6	24 751	88.2
Total deaths/person years of exposure (000s)	43 287	10601.7	28 732	11060.0

13% among women and 16–17% among men. Twin first maternities were associated with an excess mortality risk of 15% but mortality among fathers of twins was not raised. Associations between mortality risks and short second birth intervals were similar, although smaller. Among the small proportion of parents with four births, mortality was raised for those with third interbirth intervals of 18–29 months, but not for those with intervals shorter than this. Results from models 2 and 1 were close to those from the fully adjusted model, except that the association between a twin birth and female mortality was slightly stronger in models including the other fertility variables. There was more variation between different models in results for associations between very long intervals and mortality risks. In model 1 and, to a lesser extent, model 2, a first interbirth interval of 60–89 or 90+ months was positively associated with mortality but a high proportion of these parents (47% of men and 43% of women) had experienced a change of coparent; when this variable was included (model 3), the direction of the association changed. Associations between very long second interbirth intervals and mortality were similar; very long third intervals were associated with lower mortality among men in the fully adjusted model, but not significantly so for women.

Associations between other covariates and mortality risks are presented for the first interbirth interval in online supplementary table S2. Mortality risks increased with age and decreased with the period of observation and years of education. They were raised for non-married groups, particularly the divorced, and reduced with older age at first birth and higher parity. As already implied, they were raised among those who had their second child with a different coparent from the first (OR for women 1.33 (1.27–1.39); for men 1.24 (1.19–1.29)).

Cumulative and parity-specific effects

Table 4 presents parity-specific analyses of associations between mortality and short birth intervals, number of short birth intervals and average interval length. Models include all covariates previously described (model 3), other than parity. Intervals of less than 18 months between the first and second births were associated with raised mortality risks for women and men of all parities; short intervals between the second and third births were associated with raised mortality for women with three children and for men with three or four children. There was no association between a short third birth interval and mortality of the relatively small group with four children. Mortality risks were raised for women who had a twin birth first or second and no later children but not for women who had another birth after twins. Intervals of 90 or more months between successive births (not shown) were negatively associated with mortality for relevant parity groups, except in the case of the interval between the third and fourth births where the estimate of 0.90 for women was not statistically significant.

Fathers who had had three closely spaced children had higher mortality than fathers of two closely spaced children. However, for women with three children, and mothers and fathers of four children, effects tended to increase with the number of short birth intervals but differences were relatively small and not statistically significant. There was an inverse association between mortality and average birth interval length. We also undertook analyses (not shown), additionally controlling for lengths of interbirth intervals other than the one under consideration. Results were only trivially different from those presented here as correlations between birth interval lengths were weak.

Prescribed medication use

Table 5 shows results of analyses of associations between the first interbirth interval length and number of different prescription drug purchases and number of inferred diseases. Results

Table 2 Distribution by length of first interbirth interval, education, marital status, age at first birth, parity and change of coparent since previous birth

	Length of 1st interbirth interval (months)																	
	Men									Women								
	0	1–17	18–29	30–41	42–59	60–89	90+	Deaths	Person-years (000s)	0	1–17	18–29	30–41	42–59	60–89	90+	Deaths	Person-years (000s)
Education																		
10 years	1.0	13.4	25.6	21.9	18.8	11.7	7.8	15 227	2498.8	0.8	12.3	25.8	21.9	19.5	12.3	7.4	12 483	3259.3
11–13	1.0	10.0	25.4	24.7	20.9	11.4	6.5	20 083	4965.9	0.9	10.4	25.3	24.6	21	11.6	6.2	12 256	5191.7
14–17	1.2	7.3	25.5	26.4	21.8	11.5	6.5	5838	2161.2	1.2	7.8	27.6	26.5	20.6	10.6	5.8	3617	2322.7
18+	1.2	6.8	29.5	27.5	20.0	9.7	5.2	2139	975.8	1.5	6.7	29.2	25.9	20	10.7	6.1	376	286.3
Marital status																		
Never-married	2.2	5.8	19.7	19.6	19.9	16.9	15.9	882	359.0	2.4	4.5	17.4	18.2	19.2	18.1	20.4	447	287.5
Married	1.0	9.8	26.3	25.4	20.8	11.0	5.8	29 304	8543.3	0.9	10.1	26.4	25.1	20.8	11.2	5.6	18 587	8458.4
Div/sep	1.1	11.5	24.8	22.0	19.0	12.0	9.7	11 718	1573.6	1.0	11.4	25.4	21.9	19.4	12.4	8.4	6662	1815.7
Widowed	0.9	13.0	26.7	22.7	19.8	11.5	5.5	1383	125.8	0.8	13.8	27.5	22.3	18.9	10.9	5.8	3036	498.5
Age at 1st birth																		
<20	0.5	11.7	20.3	15.5	18.9	16.0	15.9	1485	260.7	0.5	13.5	24.5	19.5	18.7	13.2	10.2	5187	1505.7
20–22	0.6	12.7	24.0	20.8	19.6	12.8	9.6	9035	1746.3	0.6	12.4	25.4	22.4	19.8	11.9	7.4	9932	3408.1
23–25	0.7	11.3	25.0	23.8	20.8	11.3	7.1	13 225	3002.7	0.8	9.2	25.2	25.7	21.7	11.4	5.9	7205	2968.4
26–28	0.9	8.8	25.5	26.4	21.4	11.0	5.9	9910	2649.8	1.1	7.4	26.2	27.3	21.9	11.1	5.0	3838	1816.6
29–31	1.2	7.5	26.6	27.1	21.2	11.2	5.3	5381	1575.7	1.6	7.4	28.5	27.2	20.7	10.8	3.8	1616	836.9
32–34	1.7	7.5	28.8	27.0	20.4	10.6	4.0	2455	785.4	2.6	7.9	33.1	26.4	18.9	9.1	2.1	661	345.3
35–37	2.8	8.2	32.5	26.9	18.3	8.4	2.9	1027	363.9	5.0	9.6	36.3	26.0	16.5	5.8	0.9	222	136.4
38+	5.3	10.7	35.4	25.0	14.9	6.7	2.1	769	217.3	8.7	13.9	38.4	23.6	12.0	3.2	0.2	71	42.5
Number of children																		
2	1.0	5.8	20.2	25.1	24.8	14.8	8.4	22 112	5715.0	0.9	5.8	19.7	24.5	24.8	15.4	9.1	14 736	5872.1
3	1.1	12.5	31.2	25.5	16.9	7.8	5.0	15 093	3676.7	1.0	13	31.6	25.4	17.1	8.0	3.9	10 015	3879.1
4	1.3	21.8	36.3	19.8	11.4	5.9	3.6	6082	1210.0	1.2	22.8	37.9	19.9	11.2	4.9	2.0	3981	1308.8
Change of coparent																		
No	1.1	10.2	27.1	25.8	21.1	10.7	3.9	40 132	9946.4	1.0	10.9	27.3	25.3	20.9	10.7	4.0	26 160	10288.3
Yes	0.2	6.1	5.9	6.7	11.6	20.5	49.0	3155	655.3	0.4	3.4	8.9	9.9	15.1	23.0	39.3	2572	771.7
All	1.0	10.0	25.8	24.6	20.5	11.3	6.7	43 287	10601.7	1.0	10.3	26.0	24.2	20.5	11.5	6.4	28 732	11060.0

from mortality analyses relating to deaths during 2004–2008, including classification of birth intervals in years, are also shown. Results show a positive association between short first interbirth intervals and drug purchase and inferred number of diseases. The excess mortality among those having two children in the same or successive years is of a similar magnitude for men, but rather lower for women, as the previously shown excess mortality among those with a first interval shorter than 18 months. Results did not show the same low mortality for those with long birth intervals as found in the fully adjusted model in the main analysis. Supplementary analyses, not shown, indicate that these differences are more the result of the restriction to 2004–2008 than the use of intervals grouped in years rather than months.

DISCUSSION

Most previous studies of the implications of birth interval lengths for parental health have focused on short-term implications for mothers. We investigated longer term effects and considered fathers as well as mothers. Results showed that mortality risks at ages 40–73 years were raised for mothers and fathers who had intervals of less than 18 months between singleton births and for mothers of multiple births; that mortality risks decreased with the average length of the birth interval (for parents with more than one interval); for men, there was also some indication of a cumulative effect of experiencing more than one short birth interval. The analysis of purchases of prescription medicine similarly suggested an association between short birth intervals and poorer later health. These results are consistent with two previous UK studies which reported positive associations between short birth intervals and mortality among women,[26] and later-life health impairment among women and men.[27] Our results on associations between twin maternities and later mortality are less consistent with previous studies. Tomassini *et al*[39] found no significant raised mortality after age 45 among mothers and fathers of twins in Denmark and raised mortality or more long-term illness in only some cohorts of mothers of twins in England and Wales. However, in the analysis of Danish data, which was undertaken using indirect standardisation, it was not possible to control for socioeconomic status or compare parents of twins with other parents, rather than with the whole population including the childless.

Some previous studies have shown associations between very long interbirth intervals and adverse perinatal and short-term maternal outcomes.[6] We were unable to identify any previous studies examining the possible long-term consequences of very long birth intervals. Our results showed that very long birth intervals were associated with higher mortality risk in models including control for sociodemographic and fertility variables but that this association disappeared or even reversed when change of coparent since the previous birth was controlled. This suggests that it is the partnership disruption which often

Table 3 Associations between length of interbirth interval and mortality in 1980–2008 (ORs and 95% CIs from discrete-time hazards models), men and women born during 1935–1968 and aged 40–73 years with two to four children.

	Men			Women		
Months	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Interval 1st–2nd birth (parents with 2+ births)						
0	1.01 (0.97 to 1.12)	1.05 (0.94 to 1.16)	1.05 (0.95 to 1.16)	1.11 (0.98 to 1.25)	1.14* (1.01 to 1.29)	1.15* (1.01 to 1.30)
0>18	1.18** (1.14 to 1.22)	1.17 **(1.13 to 1.21)	1.17** (1.13 to 1.21)	1.10**(1.06 to 1.15)	1.12** (1.07 to 1.16)	1.13** (1.08 to 1.17)
18–29	1.04** (1.02 to 1.07)	1.05** (1.02 to 1.08)	1.05** (1.02 to 1.08)	1.01 (0.97 to 1.04)	1.02 (0.98 to 1.05)	1.02 (0.99 to 1.06)
30–41	1	1	1	1	1	1
42–59	1.01 (0.98 to 1.04)	0.99 (0.96 to 1.02)	0.99 (0.96 to 1.02)	1.00 (0.96 to 1.03)	0.98 (0.94 to 1.02)	0.97 (0.94 to 1.01)
60–89	1.06** (1.02 to 1.09)	1.03 (0.99 to 1.02)	1.01 (0.97 to 1.00)	1.08** (1.03 to 1.12)	1.05* (1.00 to 1.09)	1.01 (0.97 to 1.06)
90+	1.11** (1.06 to 1.15)	1.06* (1.01 to 1.10)	0.96 (0.92 to 1.01)	1.11** (1.05 to 1.16)	1.05 (1.00 to 1.11)	0.95 (0.90 to 1.00)
Interval 2nd–3rd birth (parents with 3+ births)						
0	1.06 (0.96 to 1.17)	1.09 (0.98 to 1.21)	1.09 (0.99 to 1.21)	1.14* (1.01 to 1.29)	1.17** (1.04 to 1.32)	1.18**(1.05 to 1.33)
0>18	1.15** (1.09 to 1.21)	1.13** (1.07 to 1.19)	1.13 **(1.07 to 1.19)	1.06 (0.99 to 1.13)	1.05 (0.98 to 1.13)	1.06 (0.99 to 1.13)
18–29	1.10** (1.05 to 1.15)	1.09** (1.04 to 1.14)	1.09** (1.04 to 1.14)	1.01 (0.96 to 1.07)	1.01 (0.96 to 1.07)	1.01 (0.96 to 1.07)
30–41	1	1	1	1	1	1
42–59	1.02 (0.97 to 1.07)	1.02 (0.97 to 1.06)	1.01 (0.97 to 1.06)	0.95* (0.90 to 1.00)	0.94* (0.89 to 1.00)	0.94* (0.89 to 0.99)
60–89	0.98 (0.93 to 1.02)	0.97 (0.93 to 1.02)	0.96* (0.92 to 1.01)	0.97 (0.92 to 1.03)	0.96 (0.91 to 1.00)	0.95* (0.89 to 1.00)
90+	0.99 (0.95 to 1.04)	0.97 (0.92 to 1.02)	0.91** (0.86 to 0.98)	0.92** (0.86 to 0.98)	0.89** (0.84 to 0.95)	0.83** (0.77 to 0.88)
Interval 3rd–4th birth (parents with 4 births)						
0	0.95 (0.81 to 1.10)	0.97 (0.83 to 1.13)	0.97 (0.84 to 1.14)	0.98 (0.81 to 1.18)	1.00 (0.83 to 1.20)	1.00 (0.89 to 1.21)
0>18	1.10 (0.99 to 1.22)	1.09 (0.98 to 1.21)	1.09 (0.97 to 1.21)	1.07 (0.94 to 1.22)	1.06 (0.93 to 1.21)	1.07 (0.93 to 1.22)
18–29	1.08 (0.99 to 1.18)	1.08 (0.99 to 1.18)	1.08 (1.00 to 1.18)	1.14* (1.02 to 1.26)	1.14* (1.02 to 1.26)	1.14** (1.02 to 1.27)
30–41	1	1	1	1	1	1
42–59	1.01 (0.93 to 1.10)	1.01 (0.93 to 1.10)	1.01 (0.92 to 1.10)	0.99 (0.89 to 1.11)	0.99 (0.89 to 1.10)	0.99 (0.88 to 1.07)
60–89	0.95 (0.87 to 1.04)	0.95 (0.87 to 1.04)	0.94 (0.86 to 1.03)	0.98 (0.88 to 1.09)	0.97 (0.87 to 1.08)	0.95 (0.86 to 1.07)
90+	0.93 (0.85 to 1.02)	0.91* (0.83 to 1.00)	0.87** (0.79 to 0.96)	0.98 (0.88 to 1.10)	0.96 (0.86 to 1.08)	0.92 (0.82 to 1.04)

Model 1: age; period; years of education; marital status. Model 2: + age at first birth; parity. Model 3: + change in coparent. Numbers of deaths and person years of exposure shown in table 2 and online supplementary table S1.
*p<0.05; **p<0.01.

underlies long gaps between births that has implications for later parental health.

The rather similar effects that we observe for mothers and fathers—except in the case of twins—suggest that biosocial mechanisms may underlie linkages between birth interval lengths and mortality and health in midlife and later life. These may include the results of accumulated physical, emotional and economic stress arising from the demands of having closely spaced births and raising children close in age. Such effects might be greatest for socioeconomically disadvantaged groups, but in additional analysis (not shown) we found little evidence of interactions with educational status.

We used high-quality data from a complete population with little risk of bias from non-response or attrition as might be the case in survey-based studies or of bias arising from misreporting of fertility history, a known problem in retrospectively collected data.[40] However, there are some limitations to this study. We only observed premature mortality and associations with mortality risks at older ages may be different. The data on prescription drug use were only available for a 5-year period, interbirth interval lengths could only be approximated and inferences about morbidity based on drug use may be flawed.

There are also other factors which might confound associations between birth intervals and parents' health which we have been unable to take account of. Efficiency of contraceptive use and breastfeeding practices, for example, are important determinants of interpregnancy intervals and plausibly may be associated with other health-related behaviours. Any consequent confounding would not account for the association found between multiple births and later maternal mortality. However, the mechanisms underlying associations between experience of multiple births and experience of short intervals between singleton births with health may differ, as suggested by the fact that we found that the former was associated only with mothers' mortality, whereas closely spaced singleton births were also associated with fathers' mortality. Very short, and perhaps very long, interbirth intervals may be indicative of mistimed or unplanned fertility. This might also confound associations to some extent as there is evidence that mistimed or unintended births have negative implications for later maternal health.[41] The birth of twins is also unplanned and parity-specific analysis showed that the positive association between having twins and mortality was restricted to mothers who did not progress to further births. These might include women for whom the birth of twins resulted in an eventual family size that was larger than intended and plausibly those who found raising twins particularly challenging.

The question we addressed in this paper represents a potentially important public health issue, especially as trends towards postponement of parenthood have led to an increase in parents who plan closely spaced families and, in some countries, parental leave regulations have had the effect of encouraging shorter birth intervals.[5 21 42] Additionally, the greater availability and use of assisted conception techniques has led to large increases in multiple births.[43] Norway has an advanced economy and generous parental leave, childcare and other support services for families with children[44] which, it has been suggested, may

Table 4 Associations between length of interbirth interval and mortality in 1980–2008 by parity (ORs and 95% CIs from discrete-time hazards models), men and women born during 1935–1968 and aged 40–73 years with two to four children

	Men			Women		
Months	**Parity 2**	**Parity 3**	**Parity 4**	**Parity 2**	**Parity 3**	**Parity 4**
Interval 1st–2nd birth						
0	1.07 (0.92 to 1.25)	1.14 (0.97 to 1.34)	0.78 (0.59 to 1.04)	1.36** (1.15 to 1.61)	1.00 (0.81 to 1.24)	0.90 (0.64 to 1.27)
0>18	1.19** (1.12 to 1.25)	1.17 **(1.11 to 1.23)	1.11** (1.03 to 1.20)	1.16** (1.08 to 1.24)	1.12**(1.05 to 1.19)	1.10* (1.00 to 1.21)
Interval 2nd–3rd birth†						
0		1.07 (0.95 to 1.20)	1.18 (0.97 to 1.44)		1.26**(1.10 to 1.44)	0.97 (0.74 to 1.26)
0>18		1.14** (1.06 to 1.22)	1.12* (1.02 to 1.22)		1.10* (1.00 to 1.20)	1.00 (0.90 to 1.11)
Number of intervals <18 months						
0	1	1	1	1	1	1
1	1.17** (1.11 to 1.22)	1.12** (1.08 to 1.16)	1.09**(1.03 to 1.15)	1.18**(1.12 to 1.26)	1.21**(1.12 to 1.30)	1.06 (0.99 to 1.14)
2		1.41**(1.26 to 1.58)	1.18**(1.08 to 1.30)		1.25**(1.16 to 1.35)	1.06 (0.94 to 1.19)
3			1.18 (0.88 to 1.57)			1.17 (0.79 to 1.72)
Average interval length						
0–17		1.22* (1.12 to 1.32)	1.19* (1.04 to 1.36)		1.12**(1.01 to 1.24)	1.22**(1.02 to 1.44)
18–29		1.07* (1.02 to 1.12)	1.10**(1.02 to 1.18)		1.06* (1.00 to 1.13)	1.01 (0.92 to 1.10)
30–41		1	1		1	1
42–59		0.94* (0.90 to 0.98)	0.94 (0.88 to 1.01)		0.94* (0.89 to 1.00)	1.00 (0.92 to 1.08)
60–89		0.94* (0.89 to 0.98)	0.89* (0.82 to 0.98)		0.91**(0.86 to 0.97)	0.87* (0.78 to 0.98)
90+		0.76**(0.70 to 0.82)	0.74**(0.64 to 0.87)		0.85**(0.76 to 0.94)	0.44**(0.25 to 0.77)
Deaths	22 112	15 093	6082	14 736	10 015	3981
Person years	5692.9	3676.7	1210.0	5872.1	3879.1	1308.8

Models include age; period; years of education; marital status, age at first birth and change in coparent since preceding birth.
*p<0.05; **p<0.01.
Reference category is 30–41 months.

explain why high parity in Norway does not have the same adverse effects on parental mortality risks observed in other countries.[45] In less advantaged populations, stresses attendant on having closely spaced births—and their consequences for later parental health—may be greater and need investigation. Further research is also needed to identify the mechanisms which underlie the associations reported. This would require prospective data including information on health-related behaviours and measures of stress during the childbearing and child-rearing stages of life.

Table 5 Associations between the length of the first birth interval (in years) and mortality in 2004–2008 (ORs 95% CIs from discrete-time hazards models) and indicators of use of prescription medicine (coefficients and standard errors from OLS regression models) in 2004–2008, men and women born during 1935–1968 with two to four children

Birth interval (years)	Per cent in category†	OR (95% CI) of mortality	Number of different medicines purchased	Number of diseases
Men				
0–1	10.8	1.14** (1.08 to 1.21)	0.300** (0.029)	0.141** (0.011)
2	24.5	1.05** (1.00 to 1.10)	0.073 (0.023)	0.045** (0.009)
3	24.7	1	0	0
4	15.8	0.95 (0.90 to 1.01)	−0.011 (0.026)	0.017 (0.010)
5–6	13.6	1.00 (0.95 to 1.06)	−0.012 (0.027)	0.018 (0.010)
7+	10.5	1.01 (0.95 to 1.08)	−0.026 (0.033)	0.001 (0.013)
Women				
0–1	11.1	1.07** (1.00 to 1.14)	0.129** (0.034)	0.092** (0.011)
2	24.6	1.03 (0.97 to 1.09)	−0.004 (0.027)	0.020** (0.009)
3	24.3	1	0	0
4	15.8	0.95 (0.89 to 1.01)	0.032 (0.030)	0.013 (0.010)
5–6	13.8	1.02 (0.95 to 1.11)	0.050 (0.032)	0.027** (0.010)
7+	10.4	0.97 (0.90 to 1.04)	−0.121** (0.037)	−0.021 (0.012)

Model includes: age, years of education, marital status, number of children, age at first birth and whether there has been a change of coparent since the preceding birth.
*p<0.05; **p<0.01.
†In the drug analysis.

What is already known on this subject

Short and very long interbirth intervals are associated with worse perinatal, infant and short-term maternal outcomes. Two previous studies of UK populations have suggested longer term adverse effects of short birth intervals on parental health.

What this study adds

- This study shows that Norwegian parents with short intervals between singleton births, and mothers of twins, have higher mortality and greater use of prescription drugs in late midlife than parents with interbirth intervals of 31–41 months. Parents with very long interbirth intervals also had worse outcomes—but a large proportion of these had experienced a change of coparent and when this was allowed for the direction of the association reversed.
- Delayed childbearing and greater use of assisted reproduction mean that short birth intervals and multiple births are becoming more common. This study suggests that these trends might have negative implications for later life health and further work is needed to investigate underlying mechanisms.

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