

Cohort trends in the association between age at menarche and fertility timing across 40 years in Norway

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Introduction

Age at menarche marks a key milestone in female reproductive development and has long been studied for its implications on health and fertility. Secular trends show that menarcheal age has decreased drastically across time, with the average age at menarche dropping by more than 1.5 years over a 100-year period in Norway [3]. At the same time, recent decades have witnessed increasing age at first birth and falling fertility. Historically, this trend has been linked to higher educational attainment among women, however, in recent cohorts this has shifted to a greater decrease in fertility among the lower educated groups, suggesting a convergence, or even a reversal of the gap, in fertility across educational groups [1]. Previous research on the link between menarcheal age and fertility has primarily focused on early menarche and its association with adolescent pregnancy, earlier sexual debut, and increased participation in risky behaviors [2, 5, 6]. However, emerging evidence suggests that both early and late menarche are linked to reduced fecundability and increased risk of infertility [4, 8], highlighting the need to examine fertility timing across the entire reproductive life course. Despite these findings, few studies have explored how age at menarche relates to fertility patterns beyond adolescence, including childlessness and the timing of higher order births across birth cohorts. In particular, the late menarche group remains understudied, leaving gaps in our understanding of how pubertal timing interacts with broader demographic and social changes. Addressing these gaps is essential for clarifying the long-term reproductive consequences of pubertal timing in contemporary populations.

Data and Methods

We use data on age at menarche from the Cohort of Norway (CONOR) and the Trøndelag Health Study (HUNT). CONOR comprises 11 population-based health surveys conducted between 1994 and 2003, covering 173,236 individuals from both rural and urban regions of Norway [7]. We did not include the Immigrant Health Study within CONOR as the average age at menarche differed substantially from the other surveys and fertility histories are often incomplete in the administrative data for the immigrant population. We additionally restricted our sample to individuals born between 1938 and 1978 in order to capture the full reproductive life course from ages 15-45, leaving us with an analytical sample of 62,645 women. This data is then linked to longitudinal administrative register data provided by Statistics Norway which contains information on the individuals' background characteristics and childbearing across ages 15-45. Age at menarche is divided into three categories; Early, which includes ages 7 to 11, Average, including ages 12 to 14, and Late, which includes 15 years or older. These categories were chosen both to provide a meaningful sample in each group across the sample population, as well as for consistency with prior research. Summary statistics for the sample population are provided in Table 1 below.

We utilize a piecewise constant hazard model for time to first birth by age at menarche both for the overall sample and across four 10-year birth cohorts. Hazard rates are calculated within 3-year age intervals to allow the baseline hazard of a first birth to vary across the reproductive life course. As the hazard of a birth is likely not constant across ages 15-45, this method allows for increased flexibility by capturing changes in the hazard rate across ages and without assuming that the potential influence of age at menarche is proportional across the reproductive lifespan. We then estimate hazard ratios for first birth across our 3-year age intervals and by 10-year birth cohorts with the "Average" age at menarche group as our reference category. Additionally, we estimate odds ratios for first, second, and third births using logistic regression to capture differences in the overall likelihood of each birth compared to the "Average" age at menarche group and how these associations have developed across time.

Results

Figure 1 shows the Kaplan-Meier survival plots for the transition to first birth by age at menarche across four 10-year birth cohorts. For the early menarche group, the transition to first birth is slightly quicker compared to the average

Table 1: Descriptive statistics

	(1)	(2)	(3)	(4)	(5)
	Overall	1938-1947	1948-1957	1958-1967	1968-1978
	Sample	Birth cohort	Birth cohort	Birth cohort	Birth cohort
Age at Menarche (share)					
Early (7-11)	10.4%	9.3%	10.4%	10.9%	11.4%
Average (12-14)	73.5%	70.1%	73.5%	75.1%	76.2%
Late (15+)	16.1%	20.6%	16.1%	14.0%	12.5%
Age at Menarche (mean)					
	13.2	13.4	13.2	13.1	13.0
Childless (share)					
	8.9%	7.1%	8.7%	9.5%	10.8%
Age at 1 st birth (mean)	24.0	22.7	23.6	24.6	26.2
Age at 2 nd birth (mean)	27.4	25.5	27.1	28.3	29.6
Age at 3 rd birth (mean)	30.4	28.1	30.8	31.6	32.2
Number of children (mean)	2.2	2.5	2.2	2.2	2.1
N	62,645	13,711	23,583	13,950	11,401

and late menarche groups, particularly for the older cohorts born between 1938-1947 and 1948-1957. However, in the younger cohorts, this quicker transition to first birth in the early childbearing years for those with an early age at menarche disappears and they follow a similar transition rate as the average age at menarche group. The late age at menarche group shows a slower transition to first birth across cohorts compared to the average menarche group, and this gap appears to increase across birth cohorts, with those with a late age at menarche born between 1968-1978 experiencing a markedly slower transition to first birth compared to the average and early menarche groups. Finally, the share without a first birth by age 45 across these cohorts is quite stable around 8-10%. However in the youngest cohorts, a gradient in childlessness at 45 across age at menarche appears, with 14.1% of those with an early age at menarche remaining childless followed by 12.2% among those with a late age at menarche and 10.1% of those in the average menarche group.

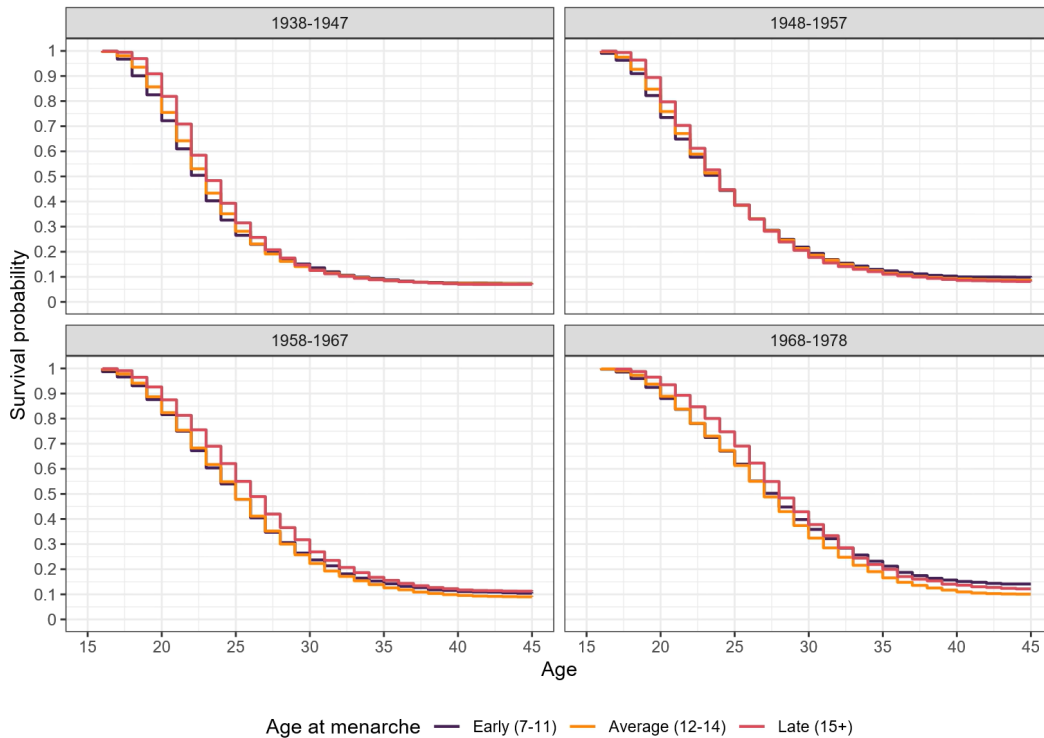


Figure 1: Kaplan-Meier survival plot for the transition to first birth by age at menarche and cohort

Figure 2 plots the hazard ratios for first birth by age at menarche estimated from the piecewise constant hazard

model across the four birth cohort groups. Those with an early age at menarche born between 1938-1947 are at a 53% increased hazard of experiencing a first birth in the earliest childbearing years from ages 16-18 compared to the average menarche group. This early transition to first birth, however, becomes non-significant across the later cohorts. In fact, the early menarche group experiences a decreased hazard of first birth compared to the average menarche group in the later ages, particularly for the youngest cohorts born between 1968-1978. In these cohorts, those with an early menarche are at a 14-23% lower hazard of first birth between ages 31-39 compared to those with an age at menarche between 12-14. Among the late age at menarche group, there is a consistent and significantly lower hazard of first birth compared to those with an average age at menarche in the early childbearing years, particularly between ages 16-21, across birth cohorts. Despite this decreased hazard in the early years, there are few significant differences in the hazard of first birth during the core childbearing years and relatively stable hazard ratios across cohorts.

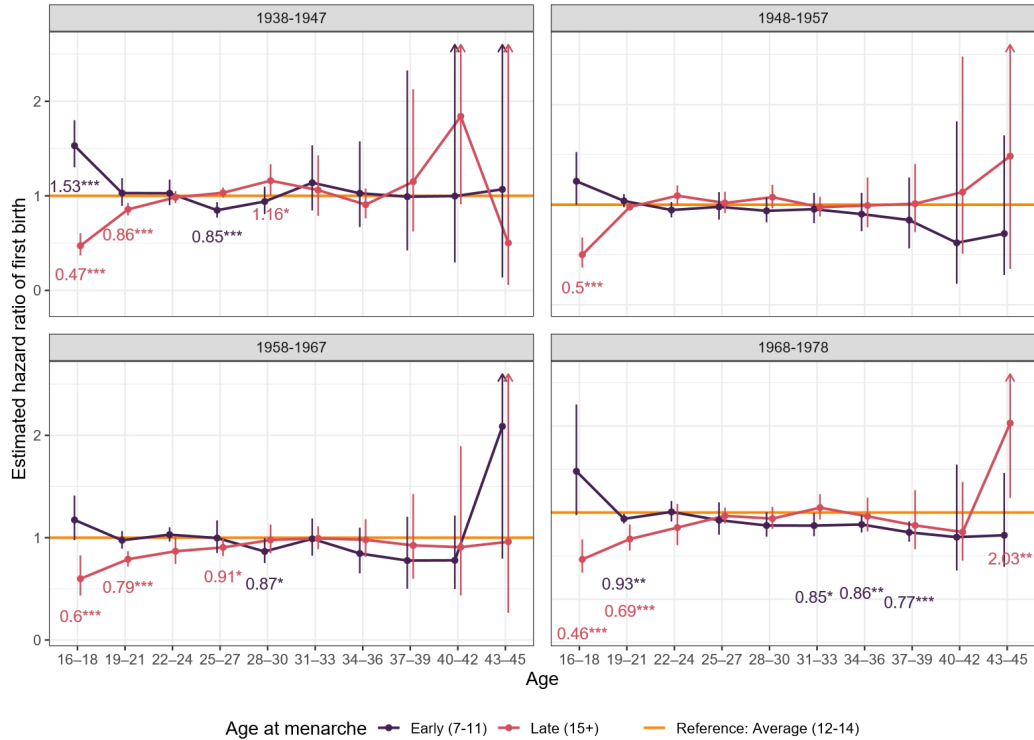


Figure 2: Hazard ratios for first birth across the reproductive life course by age at menarche and cohort. Note: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Figure 3 shows the estimates from logistic regression for the odds of experiencing a first, second, or third birth both in the overall sample and across the birth cohort groups. Overall, those with an early age at menarche have a lower odds of experiencing a first birth compared to the average age at menarche group (OR 0.82 [0.73-0.92] $p < 0.001$). However, this association only appears in the younger cohorts with the lowest odds for those born between 1968-1978 (OR 0.68 [0.57-0.81] $p < 0.001$), whereas for the older cohorts there is no significant difference in the odds of experiencing a first birth (or inversely remaining childless) for the early menarche group compared to those aged 12-14 at menarche. Similarly, those who have a late age at menarche are significantly less likely to experience a first birth compared to the average menarche group for the two youngest cohorts born between 1958-1967 and 1968-1978, with the lowest odds in the youngest cohort (OR 0.81 [0.70-0.93] $p < 0.001$).

The odds for experiencing a second birth are also lower for those with an early age at menarche across cohorts compared to the average menarche group, however this association is only statistically significant in the youngest cohorts born between 1968-1978 (OR 0.83 [0.75-0.93] $p < 0.001$). For those with a late age at menarche, the results are more mixed across cohorts, except for in the youngest cohort where those with a late age at menarche have a 10% (95% CI: 4%-17%, $p < 0.001$) lower odds of experiencing a second birth compared to those with an average menarcheal age. These associations appear to be concentrated at first and second births, however, as we find few differences in the odds of a third birth for either the early or late menarche groups compared to those with an average age at menarche.

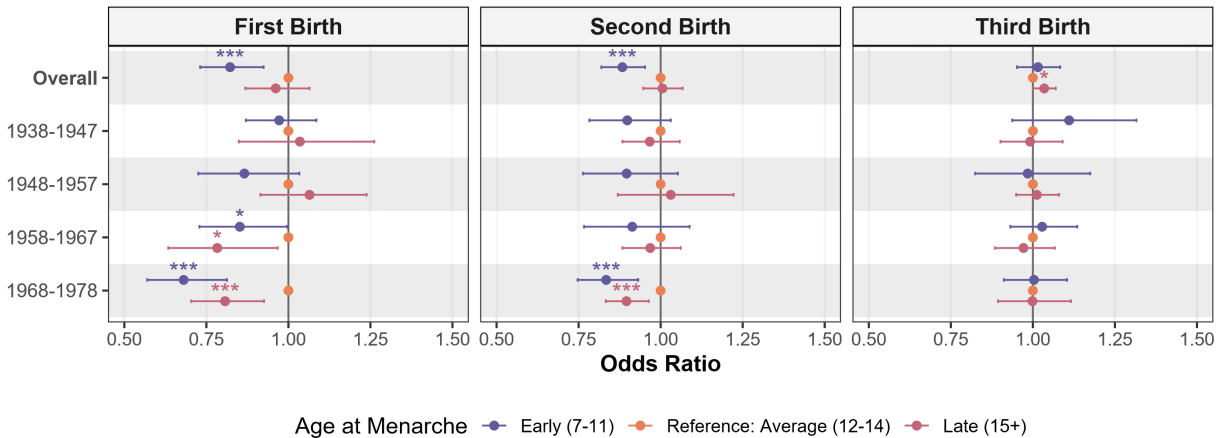


Figure 3: Odds ratios for first, second, and third births by age at menarche and cohort.
 Note: * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Discussion

Menarche represents a critical milestone in female reproductive development, and the timing of its onset can influence fertility patterns throughout the reproductive life course. Using high quality Norwegian administrative register and health survey data, this study describes this relationship across the reproductive ages and tracks how it has developed across 40 birth cohorts. We find that for those with an early age at menarche (ages 7-11), these girls experience a quicker transition to first birth in the early childbearing years compared to those with an average age at menarche (ages 12-14). This association, however, disappears across birth cohorts, with those in the younger cohorts no longer at a significantly increased risk of first birth during the teenage years. At the same time, we find those who have a late age at menarche (ages 15+) are significantly slower to transition to a first birth and experience a decreased risk of first birth during the early childbearing years from ages 16-21. Finally, we find evidence of an emerging gradient in childlessness at 45 for both those with an early and late age at menarche compared to the average menarche group for those born between 1958-1978. We also show a lower likelihood of experiencing a second birth for both groups compared to the average menarche group appearing in the most recent cohorts.

Future analyses will include expanding the piecewise constant model to second and third births in order to capture whether there are specific ages where these overall associations emerge, as well as including time-varying educational enrollment and attainment covariates to examine to what extent these changing trends may be explained by differences in education between menarche groups. By describing fertility trajectories across the entire reproductive life course over four decades of birth cohorts for both early and late menarche groups, this study moves beyond adolescent outcomes to reveal how pubertal timing shapes lifelong reproductive patterns and may contribute to growing inequalities in childlessness.

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