Biological Age Meets Couple Duration: Untangling Timing of First Births in the Context of Fertility Decline

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Short abstract

In this analysis, we examine how biological age and couple duration jointly account for the timing and achievement of first births using a novel two-time-scale event history approach. Using Finnish population register data (1987–2018) and German pairfam panel data (2008–2022), we follow childless individuals aged 18–49 from the start of cohabiting or marital unions until first birth or censoring, and stratify our results by gender and level of education. In Finland, first-birth hazards peak earlier and more diffusely, whereas in Germany, transitions to parenthood are more tightly linked to biological aging—particularly among women entering unions after age 35. Men's trajectories exhibit greater heterogeneity, with late-life peaks suggesting compensatory childbearing. We examine educational gradients in the Finnish context and find pronounced differences: Finnish women with tertiary education tend to delay childbearing within longer cohabitations, while those with primary education transition to first births early, often within shorter cohabitation durations. Our findings show that fertility postponement reflects both delayed union formation and extended childless cohabitation, varying by socioeconomic status and country context. Modeling biological and relational time simultaneously advances understanding of the mechanisms driving fertility decline and reveals how reproductive timing constraints are jointly structured by partnership and age.

Introduction and Background

This study employs a novel two-time-scale event history approach to analyze time to first birth in Germany and Finland, accounting for both biological age and union duration in a flexible manner, simultaneously. By situating fertility within couple trajectories, we capture how biological constraints and relational processes jointly shape pathways to parenthood. We ask: What patterns emerge by biological age and couple duration for time from the start of a relationship to first births? Are these consistent across country contexts? Do these patterns differ by sociodemographic categories known to be central in current fertility declines, particularly education and employment?

Declines in the transition to first-births have been a major driver of recent fertility decline in Northern and Western Europe, including both Finland and Germany, with evidence demonstrating that "perpetual postponement" can lead to increased childlessness and lower cohort fertility (Berrington, 2004; Hellstrand et al, 2021; Zeman et al, 2017). This occurs through a complex interplay of structural uncertainties (Guzzo & Hayford, 2020; Hellstrand, Nisén, & Myrskylä, 2022; Kreyenfeld et al, 2023), changing norms (Campisi et al, 2023; Guzzo & Hayford, 2020; Hellstrand, Nisén, & Myrskylä, 2022), and variations in fertility preferences across contexts and over the life course (Kuhnt, Minkus, & Buhr, 2021; Miettinen, 2010; Sturm, Koops, & Rutigliano, 2023). In Northern Europe, the fertility decline of the 2010s was predominantly accounted for by declining births within unions (Hellstrand, Nisén, & Myrskylä, 2022); Zeman et al (2017) similarly demonstrated that rising childlessness and declining first birth rates played the largest role in fertility decline in German-speaking countries. Within the Finnish context, research has also shown that a majority (two-thirds to three-quarters) of all births occur in a couple's first-cohabiting relationship with their first reproductive partner (Andersson, 2023).

Following the 2010s, a body of research has demonstrated that current and future fertility decline in Northern and Western Europe is likely to be characterized by polarized childbearing– on the one side increasing childlessness due to never- or unstable partnering, and on the other increasing younger and higher order births with less stable union trajectories (Hellstrand, Nisen, & Myrskyla, 2020; Jalovaara, Andersson, & Miettinen, 2022). These trends are characterized by increasing inequalities, with the most socioeconomically disadvantaged men and women experiencing this polarization, while advantaged couples consistently have two-child families with more stable union trajectories (Andersson, 2023; Giuntella, Rotunno, & Stella, 2022;

Jalovaara, Andersson, & Miettinen, 2022). The rise of prolonged cohabitation without children, later entry into unions, and higher rates of dissolution have reshaped pathways to parenthood in these contexts, particularly among younger and socioeconomically disadvantaged groups (Rahnu & Jalovaara, 2023).

Despite this evidence, fertility research has typically treated individual age as the primary temporal dimension over which first births occur, overlooking how the dynamics of union duration interact with biological aging to shape the risk of becoming a parent. This reflects the historical measurement of fertility, at both population and individual levels, as focused not only on women, but on married women specifically, as the main unit of analysis (for a survey of pre-2000 exceptions, see Becker, 1996). Methodological shifts towards duration-based measures signalled an openness to examine fertility patterns (as opposed to levels), however these duration-based event history models remained limited to a single-sex paradigm, which has been attributed to a lack of data or modelling restrictions (Hoem & Mureşan, 2011). However, the pre-eminent focus on *female* fertility (with more recent steps made towards comprehensively examining male fertility, see Dudel & Klüsener, 2021, for example and additional references) leaves out important dyadic dynamics in the process of childbearing.

Recent methodological advances demonstrate that life course transitions such as separation or marriage cannot be understood through single time scales alone, but require dynamic, simultaneous modeling of both biological age and relational duration (Carollo et al. 2025a). We argue that the same applies to the transition to parenthood: the likelihood of first births depends not only on how old individuals are at entry into a relationship, but also on the tenure or duration of that relationship. For example, couples entering unions at older ages may have a compressed biological window for transitioning to first births, but may experience greater economic or relational stability, which could lead to quicker transitions to parenthood. Couples that begin their relationships at younger ages may experience less stability or want to achieve additional labor market security or educational attainment and so delay first births. Accounting for both biological age and couple duration thus helps disentangle whether fertility postponement arises from later union entry, prolonged childless cohabitation, or both.

Given these trends, analyzing first births requires tools that capture both the biological constraints of reproductive aging and the relational dynamics of couple formation and stability. A two-time-scale event history approach—considering biological age and union duration simultaneously—provides a powerful way to examine whether fertility decline is driven by later union entry, longer childless periods within unions, or a combination of the two.

The purpose of including both time scales in this analysis is two-fold: first and foremost, many time-to-event analyses fail to account for multiple time scales on which events are occurring. Traditional modelling approaches select one time scale as the main time scale for the hazard function, and include additional time scales as covariates in the models, by assuming some parametric specification for these time scales' effect. In this way, these approaches limit the dimensions of interplay between the time scales, and therefore lack in flexibility for the representation of the hazard. In the case of transitions to first births, we know that the age of women at first birth has increased over recent decades, and that partnership dynamics have shifted to accommodate changing educational and employment goals (Guzzo & Hayford, 2020; Rahnu & Jalovaara, 2023). By modelling only the age of a woman at first birth, we fail to account for potential shifts in durations within couples for time to first births that accompany these secular changes. The model used in this study specifically incorporates both age at first birth and the tenure of a couple by explicitly modelling the hazard as a bivariate function of the two time scales simultaneously.

Secondly, each time scale acts as a proxy for a specific mechanism linked to the event of interest (Carollo et al, 2025b), here the first birth within a union. By using couple-duration as one of the two main time scales, we return the focus of childbearing to an intrinsically multi-person process and can gain important insights into how biological age, which is correlated with functional reproductive decline, and couple tenure, which proxies for other more social characteristics of reproduction and secular shifts in partner dynamics, work in tandem to produce modern patterns of fertility change we see today.

Data and Sample

Finnish Register Data

The Finnish Population Register records all vital and many administrative events on an annual basis for everyone living at a registered address in Finland (for reference, it is extremely difficult to use everyday services like the post office or banking services in Finland without being registered in this system). Using the Population Register of Statistics Finland, which has birth data available from 1987-2020, we select all anchors who were at least 18 and childless at the time of entry into cohabitation and whose partner was at minimum aged 18 and childless as well. We follow these couples from their entry into a cohabiting relationship (any cohabiting relationship is treated as a unique observation in this context, while any individual who is not recorded as being in any cohabiting relationship over the observation period is excluded from observation) to the event of interest, in this case, their first birth. Couples can also be right-censored when the cohabiting relation ends, when one member of the couple dies, or when the observation window is completed. For female anchors in the Finnish data, this results in a sample of 1,994,002 unique relationships, representing almost 11 million couple-years and 798,277 first births. For computational ease, we take a 10% random sample of these observations for analysis.

German pairfam Data

The German Family Panel (Panel Analysis of Intimate Relationship and Family Dynamics, pairfam) is a longitudinal panel survey spanning 14 years. About 12,000 individuals from three different birth cohorts (1971-73, 1981-83 and 1991-93) were randomly sampled in 2008, and followed up every year. In 2009, a sister study was initiated in East Germany, called DemoDiff, and since Wave 3 the two merged panels have continued as “pairfam”.

In pairfam individuals report the dates of every family related event, such as moving in with a partner, marrying or the birth of a child. Additionally, if the anchor is in a relationship at the time of the interview, the partner is also interviewed and their socio-economic characteristics (and more) are also available in the data.

For this analysis we select all anchors who were at least 18 and childless at the time of entry into cohabitation or marriage and whose partner was at least 18 and childless as well. We follow these couples up from the entry into cohabitation/marriage or the first interview (whichever happened first), until the birth of a first child, our event of interest, or censoring. Right censoring could occur if the couple separated during the panel (a competing event to the birth of a child), if the anchor dropped out of the sample, or at the last follow-up.

Data Setup

To be able to estimate the hazard for an event, here first birth, over two time scales, the data is arranged on a grid constructed over age at entry into cohabitation (on the horizontal axis) and duration of the cohabitation (on the vertical axis) (Carollo et al, 2025a). In this extended abstract, we present preliminary results from Finnish Register data and the German pairfam data; we expect to expand this analysis to more Nordic and Anglo-Saxon countries going forward in addition to conducting sub-group analyses by sex of the reference person in the couple, cohort, marital status and educational attainment.

In each sample, we generate the age of the anchor person, at the start of all unique relationships. We then generate a duration variable from the start date of any relationship to the date of the reference person's first birth. If the reference person doesn't experience a first birth during the observation window, they are right-censored by one of the following events: the date of the dissolution of the relationship, the date of death for one person within the couple (only Finnish data), or the date we stop observing couples (31 December 2020 in the Finnish data and at the last observed wave for individuals in the German data). We thus include the reference person's biological current age t, the age at the beginning of any unique couple relationship, designated as u, the duration of the unique couple's relationship, denoted as s, and an indicator for whether the couple experienced a first birth during their tenure. Because individuals cannot start a relationship until age 18 according to our sample definition (and get right-censored at age 49, meaning t can vary from 18 to 49), $t > s$ holds true for all values as t is measured in biological age and s is measured in exact duration in years (meaning s can vary from 0 to 31). t and s move at the same speed; a one unit increment in time on the t scale is equivalent to an increment on the s scale.

Methods

The hazard over the current age and duration of the relationship is equivalent to that over age at entry into the relationship and duration of the relationship:

$$\lambda(u = t - s, s) = \lambda(t, s)$$

Here, $\lambda(u, s)$ is the hazard of first birth over the (u, s)-plane, where u denotes the age at entering the relationship and s, as before, denotes the time between entering the relationship and the event of the first birth and individual trajectories run vertically from $(u, s = 0)$ to $(u, s = v)$. The (u, s)-plane is divided into $n_u \times n_s$ small bins of size $h_u \times h_s$ respectively covering the range of observed values of u and s. Within each bin the number of events, denoted by y_{jk} and the total time at risk, r_{jk} are determined (where $j = 1, \dots, n_u; k = 1, \dots, n_s$) summed over all individuals $i, i = 1, \dots, n$.

We estimate $\widehat{\lambda(u,s)}$ by two-dimensional *P*-splines (Eilers & Marx, 2021), by exploiting the correspondence between piecewise hazards and Poisson regression. For a detailed explanation of the estimating procedure, we refer to Carollo et al. (2025a, 2025c). All analyses are performed in R using the R-package TwoTimeScales (Carollo et al., 2024). The code to reproduce the analyses with the pairfam sample is available in a GitHub repository (https://github.com/AngelaCar/BiologicalAgeMeetsCoupleDuration).

Preliminary results

Below we present the preliminary results from our initial analyses of Finnish register data and German pairfam data. We begin by comparing sex-specific hazards of first birth across the two country contexts. We then provide a demonstrative sub-analysis of hazards by educational attainment for Finnish women. In the future, we plan to extend these analyses across birth cohorts, levels of educational attainment, sex, and additional country contexts.

Finland and Germany

Figures 1.a and 1.b illustrate the hazard of first birth by age at entry into cohabitation (x-axis) and duration of cohabitation (y-axis), shown separately by sex and country. Darker shading indicates greater hazards of transitioning to parenthood. The overall peak hazard is lower in Finland (0.14) than in Germany (0.20) across both sexes, but the timing and shape of the hazard surfaces differ markedly across the two settings.

Among women, Finnish and German patterns diverge in important ways. While Finnish women exhibit similar ages at union entry as German women, they reach their highest hazards of first birth more quickly—typically within five years of starting cohabitation. Their hazard surfaces are less consistently structured across the two time scales, with pockets of higher hazards among women under 20 with around two years of cohabitation and among those with 5–10 years of cohabitation. The relatively low hazards at age 20 and 2.5 years of cohabitation suggest these are representing secular shifts in cohort preferences for cohabitation and other life goals, which we expect to visualize more clearly when disaggregating by birth cohort. The clearest peak occurs among Finnish women entering cohabitation between ages 27 and 30, who transition to first birth relatively rapidly. By contrast, German women’s trajectories more closely follow biological aging: younger women remain childless for longer periods, while women entering unions after age 35 typically transition to motherhood quickly, with hazards dropping sharply if childbearing has not occurred within two years.

Finnish men resemble Finnish women in their hazard profiles, with somewhat more diffuse age patterns. German men, however, follow a very different trajectory from German women. Their hazard surfaces are bimodal, with one peak among those who began cohabiting in their mid-20s and transitioned after 5–10 years, and a second among men entering unions around age 40, who transition almost immediately to fatherhood. This late-life concentration may reflect compensatory strategies, where men who may be disadvantaged on partnership markets wait until they have more stable resources to form a union and then immediately transition to childbearing. Alternatively, this pattern may be demonstrating a reverse causality effect, where union formation at older ages occurs precisely at the point of childbearing.

Taken together, these results suggest that in both countries women's first-birth trajectories are more tightly constrained by biological age, while men's are more variable. This gender divergence is much more pronounced in Germany than in Finland.

Educational Attainment

Figure 2 shows the hazard for first births among Finnish women who had different levels of educational attainment at entering their first cohabiting union. Among women with only primary education, hazards are highest at very young ages (under 20) and short durations of cohabitation, reflecting an alternative pathway to parenthood reminiscent of the patterns described in the U.S. context in "Promises I Can Keep". A second concentration appears at ages 25–30, also at short durations, suggesting that while some women with primary educational attainment wait until normative childbearing ages, they do not postpone childbearing in order to achieve other life-course markers such as stable employment.

Patterns among women with secondary education are more heterogeneous. Many enter cohabitation at relatively young ages but delay childbearing for 10 years or more, consistent with postponement linked to further schooling or career stabilization. At the same time, a strong hazard is observed among those aged 25–30 with short durations, producing a divide between early union formers who postpone and those who transition quickly once normative parenthood ages are reached.

Among tertiary-educated women, union duration is more decisive than age at union entry. Hazards peak after 5–10 years of cohabitation, regardless of when the union began, indicating a normative expectation of waiting within the relationship before progressing to parenthood. After age 25, hazards rise steeply, reflecting the combined effects of relationship duration and biological constraints.

Discussion

Although declining fertility is often presented as a "population problem," there are other, more important demographic takeaways from this work, as sexual and reproductive freedom for individuals and couples should be universally promoted and policy solutions to aging societies need to be investigated. Here we find that despite similarities in fertility decline, heterogeneous contexts lead to different patterns of life course trajectories, which lead to different patterns of achieved fertility first births by age 49. Initial evidence from Hellstrand et al (2021) suggested declining fertility in the Nordics was characterised by socioeconomic stratifications; we show that these are very real and present in the combined context of cohabitation and educational gradients. We also preliminarily find evidence to support alignment, particularly among women, between perceived biological limits to fertility, and fertility behavior, and that these perceptions align closely with fertility behavior, particularly among German women and men.

We also see from our results that if an individual does not end up in a long-term, cohabiting relationship by around the age of 30, it is unlikely that there is enough time for them to recuperate even a first birth; this is especially true for women and is likely related to the amount of time and investment in partnerships needed and the potential reproductive declines over age. This suggests that future research focusing closing the gap between desired and achieved fertility should examine characteristics of "successful" early coupling, limits to reproductive lifespans, whether decoupling fertility from partnership leads to successful reductions in these gaps, and whether the family dynamics and health outcomes for children from later, "rushed" time to first birth cohabitations are similar to children born from longer-term, earlier-starting relationships. Because births within couples do not account for the universe of first births, we also should generate additional evidence on first births in non-cohabiting contexts, for example if these are primarily occurring amongst couples who "live apart together."

Figure 1.a.: Hazard of first birth, by sex, age at start of cohabitation, and duration of relationship, German pairfam data

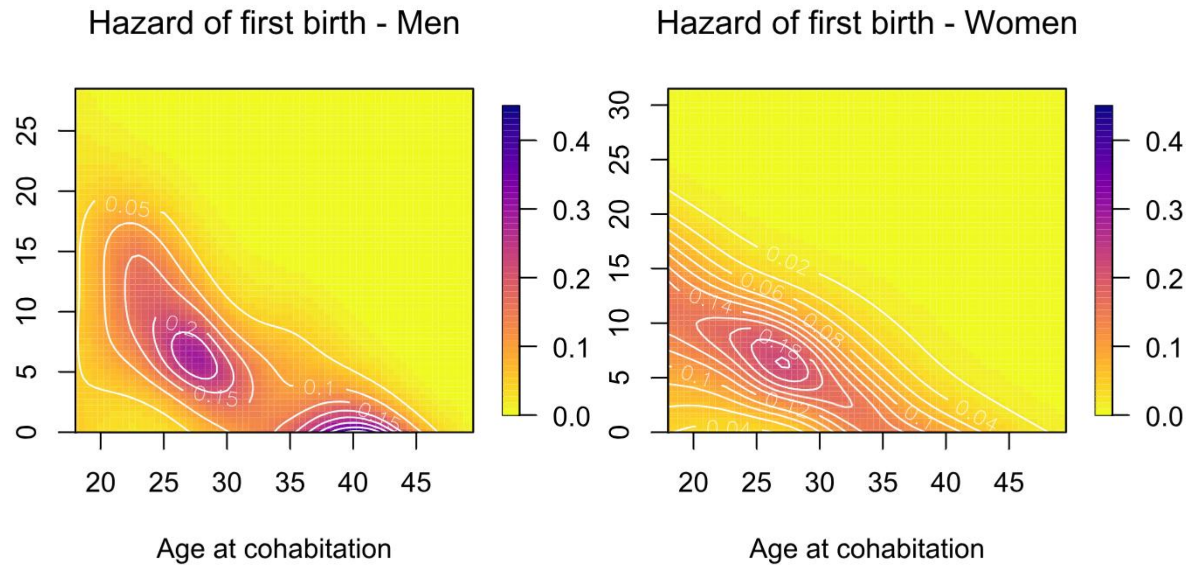


Figure 1.b: Hazard of first birth by, age at start of cohabitation, and duration of relationship, Finnish Register data

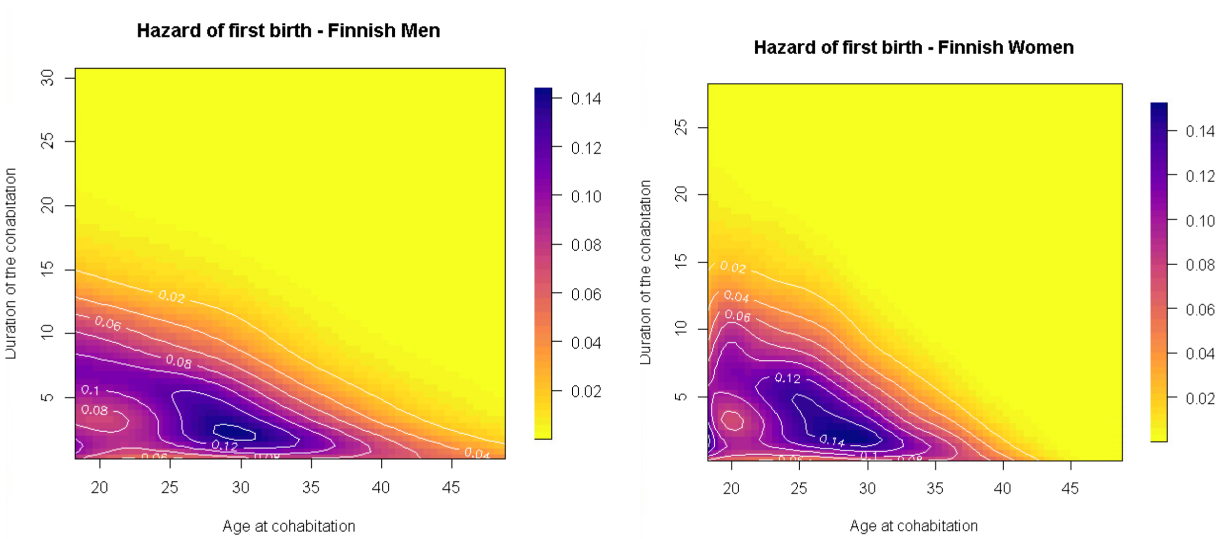
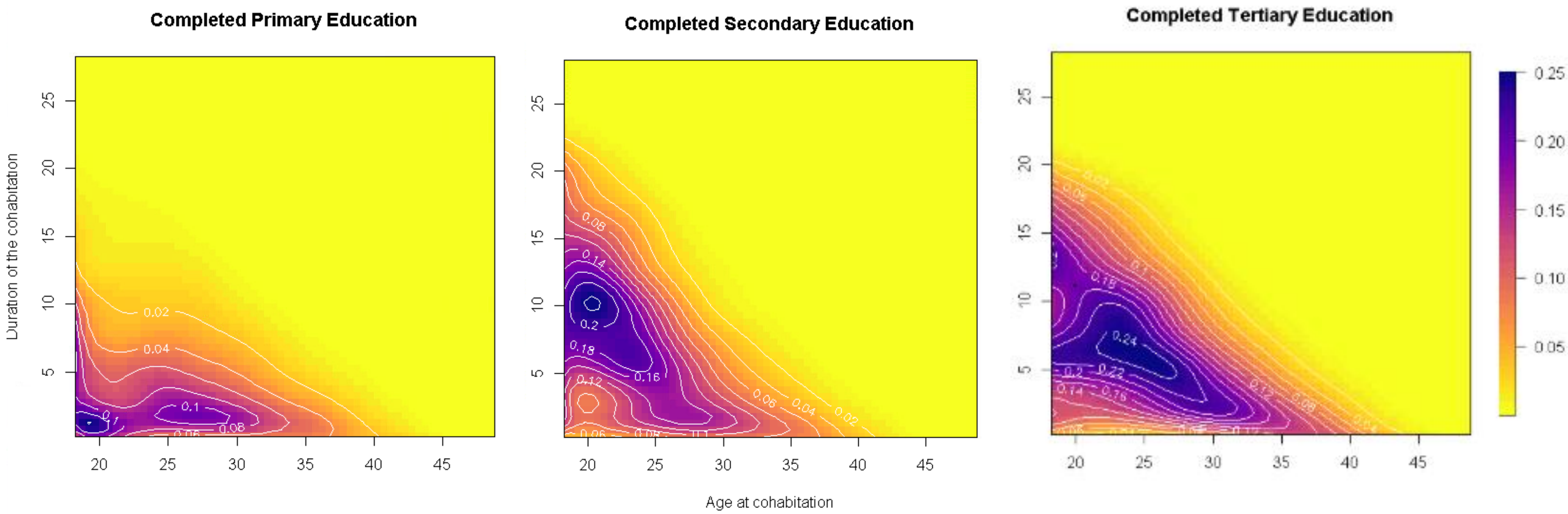


Figure 2: Hazard of first birth by age at start of cohabitation, duration of relationship, and educational attainment at entering cohabitation, Finnish Register, Female data



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