HOW EXTRINSIC MORTALITY AFFECTS AGE AT MENARCHE AND FERTILITY IN A 1970 BRITISH COHORT

by

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A thesis

submitted in partial fulfillment

of the requirements for the degree of

Master of Arts in Anthropology

Boise State University

August 2019

BOISE STATE UNIVERSITY GRADUATE COLLEGE

DEFENSE COMMITTEE AND FINAL READING APPROVALS

of the thesis submitted by

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Thesis Title:	How Extrinsic Mortality Affects Age at Menarche and Fertility in a 1970 British Cohort

Date of Final Oral Examination: 30 April 2019

The following individuals read and discussed the thesis submitted by student Kimberly Marie Neagle, and they evaluated the student's presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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The final reading approval of the thesis was granted by Kristin Snopkowski, Ph.D., Chair of the Supervisory Committee. The thesis was approved by the Graduate College.

ACKNOWLEDGEMENTS

Thank you to my mentors, Dr. Kristin Snopkowski and Dr. Kathryn Demps who provided excellent guidance through this whole process, personally and academically. A special thanks to Robert McNair and the McNair Scholars Program, because of you many first-generation college students with underrepresented backgrounds (like myself) can achieve their dreams of obtaining a graduate degree. I would also like to thank all my family and friends who helped me along this journey. Tina Garcia, Bertha Chagolla, Louie Neagle, Jorge Barajas, Michael Stephens, Tiffany Stephens, Delsi Palmer, Danny Palmer, Daniel Palmer, Lilly Palmer, Monroe Martinez, Alijah Castillo, Diamond Martinez and Bella Martinez, you are my motivation and because of all of you, I DID IT!

ABSTRACT

Extrinsic mortality is the likelihood of mortality that is not conditional on reproductive effort. It does not depend on a person’s behavior and cannot be changed by altering behavior. Theoretically, extrinsic mortality plays a major role in the evolution of life history and the variation in reproductive strategies. Using life history theory as a framework, with higher extrinsic mortality cues women should speed up reproduction to maximize fitness in uncertain or risky environments, and in environments with little risk, women can allocate their energy to somatic development and in this time, accrue resources such as education and career opportunities. Thus, I predicted that higher extrinsic mortality cues would be associated with (1) earlier age at menarche, (2) higher number of offspring, and that (3) menarche would mediate early life factors and fertility. This study examined how extrinsic mortality cues, measured by parental separation, residential moves, and violence, affects age at menarche and fertility in a sample of 8,917 women from the 1970 British Cohort Survey. The results show that living with both natural parents at age five and being disabled predicted earlier age at menarche. Not having a disability and having more siblings were the only factors that predicted higher fertility, and age at menarche was not a mediator of the relationship between early life factors and fertility. The results did not support my predictions and may support the child development theory that argues early childhood family experience alters adolescent reproductive development rather than long-term effects like fertility.

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LIST OF ABBREVIATIONS

ADP	Adaptive Developmental Plasticity
SES	Socioeconomic Status
SPSS	IBM Statistical Package for the Social Science
MAR	Missing at Random
BCS	1970 British Cohort Survey

CHAPTER ONE: INTRODUCTION

Life History Theory

Evolutionary explanations of reproductive behavior rely on life history theory. Three biological processes make up an individual's life history: reproduction, growth, and maintenance (Gadgil & Bossert, 1970). There is a limited amount of energy and resources that any organism has available and it needs to allocate resources to these different processes. Life history theory assumes that behaviors, phenotypes, and development, are shaped by natural selection, to optimally distribute energy to somatic or reproductive effort (Chisholm, 1993). Somatic effort is maintenance or survival and reproduction effort is mating or parental effort. Over long periods of evolutionary time, species develop in varying conditions, and specific traits can be selected for adaptation to the environment (Stearns, 1976).

Life history theory describes two tradeoffs of energy allocation to maximize fitness: (A) current versus future reproduction and (B) quantity versus quality of offspring. Due to the high cost of reproduction, the first tradeoff is between current and future reproduction. Current reproductive effort can reduce future reproduction by lowering fertility or increasing the risk of mortality (Borgerhoff Mulder, 2000; Hill & Kaplan, 1999). However, environmental conditions can explain variation in life history strategies, for example, if survival depends on investment in growth and development, and mortality is low, then natural selection can favor future reproduction and investing in the quality of offspring (Nolin & Ziker, 2016). Another potential trade-off is between quantity and quality of offspring. Generally, the greater number of siblings may result in smaller body size or less parental investment (Borgerhoff Mulder, 2000). This is when reproductive effort is either allocated to increasing the number of offspring or increasing the quality of the offspring. Natural selection may favor investment in offspring quantity when mortality is high, particularly when parental investment cannot alleviate mortality risks. In contrast, investment in quality may be favored when the environment is competitive. Parents have limited resources to invest and this reduces the resources available for each additional offspring (Hill & Kaplan, 1999). The budget of energy and resources an individual possess is not infinite, therefore both tradeoffs are inevitable (Borgerhoff Mulder, 2000)

These trade-offs have also been described using the terms “r- and K- selection”. However, no species is completely r- or K- selected and instead are on a continuum, which can be studied in empirical ways (Ellis, Figueredo, Brumbach, & Schlomer, 2009; Figueredo et al., 2005; Pianka, 1970; Rushton, 1985; Weizmann, Wiener, Wiesenthal, & Ziegler, 1990). A K-selected species is consistent with a focus on the trade-off of somatic effort over reproductive effort (long development periods), and parental effort over mating effort (few offspring with high investment). This leads to greater stability in development, health, and investment in offspring. More r-selected species have reproductive strategies with opposite expectations (Figueredo et al., 2005). Being more r-selected results in a prioritization of mating effort over parental effort, reproductive effort over somatic effort, faster development, and production of greater numbers of offspring with low investment (Figueredo et al., 2005).

Adaptive Developmental Plasticity

Human life history traits reveal considerable receptiveness to ecological context (Kuzawa & Bragg, 2012). Adaptive developmental plasticity (ADP) details conditions in which external factors during a person's development influences their adult phenotype (Nettle & Bateson, 2015). The informational ADP hypothesis argues that over evolutionary time, three relationships act together, the developmental input, the adult environment and phenotype. The developmental input or cue will give information about the future adult environment predicted over evolutionary time and develop a phenotype specifically suited for the predictive environment (Nettle & Bateson, 2015).

"If a particular form of phenotypic plasticity enhances an organism's probability of surviving directional selection at the population level, it may lead to an adaptive evolutionary response" (M. E. Jones et al., 2008). For example, an infectious disease has dramatically increased in the Tasmanian devil population as a new source of extrinsic mortality, and it is making changes to their life history. With the disease killing the species within the first year of contracting it, females only have one breeding opportunity and reach sexual maturity 16 times faster. This coincides with life history theory's prediction that in an environment with high adult mortality, earlier reproduction will arise (M. E. Jones et al., 2008).

Extrinsic Mortality

Researchers have hypothesized that risk of mortality is the factor that influences where an organism falls on the continuum of reproductive strategies (Chisholm, 1993; Gadgil & Bossert, 1970). Extrinsic mortality is the likelihood of mortality that is not conditional on reproductive effort (Quinlan, 2010). It does not depend on a organisms behavior and cannot be changed by altering behavior (Pepper & Nettle, 2014; Quinlan, 2010; Uggla & Mace, 2015). Theoretically, extrinsic mortality plays a major role in the evolution of life history and the variation in reproductive strategies, and there are tradeoffs according to the environment a person develops in. With higher extrinsic mortality cues, an individual should speed up reproduction to increase fitness in uncertain or risky environments allowing a potentially longer lifespan and allocating energy to reproduction instead of somatic development. In environments with little risk, individuals can allocate their energy to somatic development and in this time, accrue resources such as education and career opportunities, allowing them to have either more or higher quality offspring in the future (Quinlan, 2010).

Bet-hedging theory argues that when extrinsic mortality cues are high, a short-term reproductive strategy may be optimal because it can maximize the number of offspring. In this scenario mating effort is prioritized over parenting effort, to acquire mates. Conversely, a long-term reproductive strategy (future reproduction with high investment) is optimal when mortality rates are low and there is minimal intergenerational variation (Chisholm, 1993). Parenting effort is favored to ensure offspring survive long enough to accrue reproductive fitness benefits (Trivers, 1972).

Promislow and Harvey (1990, 1991) state that the ratio of adult to juvenile mortality is also important to life history trait adaptations, but only when mortality is high. When juvenile mortality is low but adult mortality is high then reproducing early with a mating effort reproductive strategy is predicted. When the opposite occurs, restrained early breeding is predicted (Promislow & Harvey, 1990, 1991).

This is also the case with perceived extrinsic mortality. Pepper and Nettle (2014) found that in North American adults of lower socioeconomic status (SES) perceived higher extrinsic mortality cues in their environment and did not invest in their health, compared to people of other socioeconomic status' who did not have this perception (Pepper & Nettle, 2014). A similar study found that individuals of lower socioeconomic status had a positive association between extrinsic mortality cues and higher risk of preventable death, they were also more likely to neglect their health (Uggla & Mace, 2015).

Sensitive Periods in Childhood

Early life conditions may influence reproductive strategies later in life (Draper & Harpending, 1982). There is an evolutionary function of early life experiences during the first five to seven years of childhood, which helps children learn and understand resource availability and predictability in their environment, while learning who to trust and building interpersonal relationships, which may influence later reproductive decisions (Belsky, Steinberg, & Draper, 1991; Draper & Harpending, 1982).

From an evolutionary perspective using life history theory as a framework, reproductive timing is directly related to two different life course trajectories. The slower course is related to delayed (future) reproduction and allocating resources to produce higher quality offspring, the faster course entails faster (current) reproduction and allocating resources to higher quantities of offspring (Griskevicius, Delton, Robertson, & Tybur, 2011). The decision of where a person falls on the continuum may be influenced by early life environments and events.

During infancy and childhood, stressful family environments can lead to an acceleration of reproductive developments in later life (Quinlan, 2003). When children are developing in stressful environments there may be less parental care, leading to insecure attachment to their parents, and having troublesome behavior, earlier age at menarche and first sexual activity. This can be perceived stress or a child’s direct experience that will result in developing an understanding of what relationships in the future will bring (Belsky et al., 1991). Children who experience early family stress tend to mature earlier than those who have not (B. Jones, Leeton, McLeod, & Wood, 1972; Surbey, 1990). If those in uncertain environmental contexts leave more offspring by possessing the plasticity to mature earlier, this may represent adaptive phenotypic plasticity (Rickard, Frankenhuis, & Nettle, 2014).

Chisholm and colleagues (2005) conducted a study on 100 Australian women examining early stress and how it relates to age at first pregnancy and other reproductive developments. They measured stress in eight ways, including parental violence, parental separation before the age of 10 years old, relationship with parents, mother and father absence, and parental death. They combined these measures into a single variable called total early stress, with more early life stress represented by higher scores. Total early stress was strongly associated with age at first birth, even after controlling for education, income, and ethnicity (Chisholm, Quinlivan, Petersen, & Coall, 2005), suggesting that adversities during the sensitive childhood periods may affect adult reproductive strategies.

Parental Separation

Attachment theory may help explain the mechanism by which reproductive strategies are developed. This theory states that children develop internal working models of relationships based on the attachments to their caretakers by the ages of five to seven (Bowlby, 1969). They are able to perceive social relationships, feel secure, and feel separation anxiety from their caretakers that prompts them to go back to their mothers. The children who are securely attached experience "positive expectations about self-with-others that are resistant to change" (Chisholm, 1993). Children who have insecure attachments to parents may use this as a cue to a high mortality environment (Chisholm, 1993).

Early work by Draper and Harpending examined the link between father absence in early childhood and outcomes expressed later in an individual’s life (1982). They argued that the earlier the separation from a father, the stronger the effects on the child’s behavior at later ages. In general, they found that girls who develop in father-absent households shows earlier sexual interests, and are more likely to have short-term pair bonds (Draper & Harpending, 1982). However, Quinlan (2003) found that while father absence is associated with reproductive developmental outcomes, the quality of direct parent care during early childhood also predicts female reproductive development (Quinlan, 2003).

The quality of direct parental care received during childhood may determine adult reproductive strategies. With high levels of parental investment, these researchers argue, offspring should delay reproduction because there is the indication that the environment requires parental care and should be accompanied by a longer developmental period. Low parental investment accelerates maturation because it’s been found to not be beneficial to delay reproduction (Quinlan, 2003). Quinlan demonstrated this in a study including 10,847 women in the United States. He found the timing of parental separation and number of changes in caretaking environment predicted age at menarche, first pregnancy, and first sexual intercourse. Women with parents separated before 6 years of age were at two and a half times greater risk of early pregnancy. The risk of early reproductive development decreased as women lived with both parents longer. Also, women who had three or more changes in their caretaking environment showed five times the risk of early pregnancy. There were no associations when individuals lived with a stepfather (Quinlan, 2003).

However, non-western studies failed to find a relationship between father absence and menarche (Anderson, 2015; Azcorra, Rodríguez, et al., 2018; Kyweluk, Georgiev, Borja, Gettler, & Kuzawa, 2018; Sohn, 2017; van Brummen-Girigori, Odette, & Buunk, 2015). In Malaysia, for example, nutritional resources stress is associated with late ages at menarche and father absence was not. However, if father absence affects resources negatively, it could also delay age at menarche. They did find that later age at menarche was associated with a large family size. Siblings compete for resources therefore a larger family size would lower resource availability, even in wealthy settings. They also found that father absence in later childhood was more important than any other time (Sheppard, Snopkowski, & Sear, 2014).

A recent study on age at menarche in mothers and daughters from Yucatan, Mexico, analyzed whether the living conditions are associated with the age at menarche in daughters. To examine living conditions, they looked at number of siblings, quality of housing, and father absence in pre-menarcheal years. They found that mother's age at menarche, number of siblings for both mother and daughter, and household conditions were significantly associated with age at menarche, but father absence was not associated with age at menarche at all (Azcorra, Rodríguez, et al., 2018).

Another study on a population from the Caribbean island of Curaçao measured early and later father absence. Girls who experienced early father absence were found to have a significantly earlier age at first intercourse. They were also significantly less interested in marriage and grandchildren. They found no significance in age at menarche, number of sexual partners, or wanting to have children (van Brummen-Girigori et al., 2015).

Kyweluk and colleagues (2018) studied women in the Philippines. They examined nutrition and environmental risk, including parental absence and sibling death, and the association with age at menarche. They found that cues of an uncertain environment did not predict age at menarche but instead weight gain during infancy and nutrition were predictors of earlier age at menarche. They concluded that nutrition in childhood and infancy has a stronger influence on age at menarche than psychosocial cues. They also found later age at menarche in risky environments instead of earlier (Kyweluk et al., 2018). While examining Indonesian women, Sohn (2017) found no relationship between father absence and age at menarche. He concluded, based on the literature review and his null findings that the effects of father absence are not universal (Sohn, 2017).

Finally, a study in Cape Town, South Africa examined age at menarche, age at first sexual intercourse, and age at first pregnancy. Childhood stress was measured by father absence by age six and childhood exposure to violence. They did not find an effect on age at menarche but did for age at first sex and first pregnancy. Menarche was not predicted by father absence or violence exposure, but age at first sex and first pregnancy was (Anderson, 2015).

In sum, parental separation has been empirically tested in the western context using attachment theory as the framework to show acceleration of age at menarche, while non-western studies have not. While these effects seem consistent in western contexts, in places that may be considered non-western, the effects of father absence seem to be much more variable. In general, it is more likely to find father absence effects on reproductive strategies during adolescence like first sexual activity and first pregnancy rather than father absence effects on menarche.

Parental Investment

Natural selection can favor mechanisms that dictate the pace of reproductive scheduling in response to early adversities (Nettle, Coall, & Dickins, 2011). A longitudinal study on 4,553 British women found predictors of parental investment, including low birthweight, short breastfeeding duration, mother separation, frequent residential moves, and low parental investment had significant effects on age at first pregnancy. Specifically, low paternal involvement reduced the age of first pregnancy by 0.74 years, separation from mother under five years old decreased the age at first pregnancy by 0.64 years, residential moves in childhood decrease the age at first pregnancy by 0.54 years, and short breastfeeding duration decreased age at first birth by 0.50 years (Nettle et al., 2011). In this study researchers also created an early life adversity index by summing short breastfeeding duration, separation from mother, low paternal investment, and residential moves in childhood. The results showed an additive effect, where each additional exposure to early life adversity, lowered the age at first pregnancy by nearly half a year (Nettle et al., 2011).

Illness

While some researchers have claimed that early first reproduction is a likely result of high extrinsic mortality cues due to predictions from life history, other researchers believe that other mechanisms might be at play. For instance, the internal prediction hypothesis states that individuals have a sense of their internal state and if that is compromised it may be adaptive to begin reproduction at an earlier age (Rickard et al., 2014). It relies on earlier circumstances that effect the body long-term and doesn’t rely on environmental cues that inform an individual about future conditions. These adversities, which may cause molecular or cellular damage that increases the risk of mortality, and are predicted to result in individuals speeding up their reproductive development (Rickard et al., 2014). The current internal state is used to figure out which strategy would be best in the later part of life (Chisholm, 1993; Nettle et al., 2011; Rickard et al., 2014).

Age at first reproduction has been compared in the 1970 British Cohort Survey participants who have chronic diseases and those who do not (Waynforth, 2012). Their results aligned with the prediction that those with chronic disease were associated with earlier first reproduction, even though chronic disease was uncorrelated with other measures of ecological stress including father absence and socioeconomic status. These individuals were 1.6 times more likely to have a first child by 30 years of age (Waynforth, 2012).

The literature review illustrates the use of life history theory to make predictions about reproductive strategies based on early life events. Empirical studies show parental separation, parental involvement, and chronic illness in the sensitive periods of childhood accelerate age at menarche in western contexts. However, it is unclear whether this affect is seen when examining the overall fertility of a woman and if menarche is the factor explaining the association between early life factors and fertility.

Predictions

This study uses the 1970 British Cohort Survey (BCS) data to test the predictions that higher extrinsic mortality cues will accelerate reproductive strategy. Extrinsic mortality cues are measured by parental separation, exposure to violence, and residential moves. I predict that higher extrinsic mortality will be associated with (1) earlier age at menarche and, (2) higher number of offspring, and (3) that menarche will mediate early life factors and fertility.

CHAPTER TWO: METHODS

Cultural Context

In 1970 the fertility rate in the United Kingdom was 2.44 births per woman which has decreased to 1.80 births per woman in 2016 (“The World Bank,” 2019). For age at menarche a generational study examined women born in 1908-1993 in the United Kingdom. They found a secular trend showing a steady decline from 1945 (12.6 years) to 1993 (12.3 years) (Morris, Jones, Schoemaker, Ashworth, & Swerdlow, 2011).

The National Health Service Act of 1946 enabled the entire population to receive free, universal, and comprehensive health care services, and this is still being practiced today (Organization, 1999). The divorce rate was at 5.9 per 1,000 married people in the population in 1971 and raised to 10.8 in 2012 (Guardian, 2016). The life expectancy was 71.97 years and has similarly increased to 80.96 years in 2016 (“The World Bank,” 2019).

Unemployment in the United Kingdom exhibit a cyclical trend. In 1970 unemployment was at about 2.5% of the population, this dramatically increased to about 13% in 1982, and down to about 6% in 2013. In 1973 inflation rose by 20% due to strengthening unions, growth in credit, and increase in oil prices. Prices for houses also rose because of an increase in income and a tax relief act (Pettinger, 2016). The type of crimes in the United Kingdom have not changed much in the last 25 years with vandalism and thefts accounting for the majority. In 1981, 20% of crimes were violent only raising by 3% in 2006 (Jansson, 2007).

Sample and Participants

Data were collected from the ongoing 1970 British Cohort Survey which followed 17,196 people born in a single week in England, Scotland, and Wales, referred to as cohort members. The multi-purpose, longitudinal survey gathered data at various ages of the cohort member's lives (birth, 5, 10,16, 26, 30, 34, 38, 42, 46). Information was collected on health, education, development, economic indicators, and other factors. The survey was conducted via face-to-face interview and telephone (Elliott & Shepherd, 2006).

During the cohort members childhood, tracing was available through school records, once they completed their education, researchers sent out annual reminder mailings on their birthday, and contacted them by phone. The main cause of participant attrition is the cohort member moving to a new address and not updating their information. Another reason is refusal to participate, which was 7.6% of the 34 year old sweep (Elliott & Shepherd, 2006).

Variables

Dependent Variables

The outcome variables were age at menarche (continuous) and overall fertility (count) at age 42. Age at menarche was self-reported by the cohort member at age 16. The question asked, "give the age when you had your first period", with instructions to tick one box with the categories: 10 years, 11 years, 12 years, 13 years, 14 years, and 15 years. Overall fertility is a derived variable measured by total number of own living children and number of own children who have died at the age of 42.

Independent Variables

Extrinsic mortality cues were measured in a variety of ways, including parental changes, residential moves, and violence. Parental change variables included if the mother and child were ever separated for a month or longer, if the child lived with the same parents since birth, if they ever lived with only one parent, and the number of natural parents they were living with at 5 years of age. The residential moves variable asked for the number of addresses the subject lived at from birth to 10 years of age. Violence was measured by asking the cohort member at age 16 if they had ever had force used against them, ever received violent threats, if they had seen or taken part in a fight, how safe they felt walking alone, and the average derived score of worriedness about violence (higher score indicating more worry).

Other predictor variables were disability status and siblingship. Disability status was completed when the participants were 10 years old and asked if the subject had a physical or mental disability that interfered with everyday life. Siblingship referred to the number of siblings the cohort member had in their family and what their birth order was.

Mediators

Additionally, whether the participant had evidence of puberty at age 10, along with age at menarche were used as mediators representing part of a reproductive strategy. Therefore, models were ran with and without them.

Controls

The analysis controlled for socioeconomic status of the cohort member’s family at age 10 (measured by the gross weekly income), both parent’s age at participants birth, both parent’s and cohort members age at completed education, and highest education qualification. Parent’s highest education qualification was taken as the highest qualification of either parent.

Statistical Procedure

The statistical procedure was completed using IBM Statistical Package for the Social Sciences (SPSS) version 22. The dataset has an overall sample size of 8,917 women (about half of the original sample). However, due to participant attrition, the sample size for individuals responding to all variables in the study is only 1,500. To make up for the missing values a multiple imputation with the assumption that the data was missing at random (MAR) was executed on all variables. A multiple imputation uses other statistical procedure to predict the missing values based on existing data. The assumption that data was missing at random means that missing data can be predicted from other values and it may be because individuals are less likely to answer certain questions than others (Donders, van der Heijden, Stijnen, & Moons, 2006). There were five imputed datasets created and the results were pooled.

Models

Three models were tested using SPSS software. The first model examined all variables (independent and control variables, see Table 1), predicting age at menarche. Since the dependent variable is continuous, a multiple linear regression was performed. The second model included all variables (independent and control variables) to predict fertility, excluding age at menarche. Finally, the third model included evidence of puberty and age at menarche to determine if they were mediating variables between the independent variables and fertility. To test the second and third model a Poisson distribution was executed because the dependent variable (fertility) is a count variable. Predictors were considered significant when $p<0.05$.

CHAPTER THREE: RESULTS

Descriptive statistics of the dependent, control, and independent variables are showing below in Table 1. Out of the 8,917 women in the sample, the average age of menstruation was 12.5 years and they had an average of 1.79 children. Extrinsic mortality cues were measured by a variety of variables. Most women reported not being separated from their mothers (95%), living with the same parents since birth (85%), never living with only one parent (82%), and having both natural parents in the household (89%). Extrinsic mortality cues were also measured by the number of residential moves in the subject's childhood, which averaged to 1.4 moves. The final measure was violence. Again, most of the women in the sample responded as never having force or threats used against them at 92% and 93%. Of this sample 45% of women had never seen or taken part in a fight, 48% had seen a fight and 8% had taken part in a fight by age 16. The perception of safeness was measured by asking how they felt walking alone, half said they felt fairly safe and 34% reported to feel a bit unsafe. Disability status was used to examine the internal prediction hypothesis and only 7% of participants are disabled. Siblingship was also measured in the number of siblings and the birth order of the cohort members. Women on average had 1.58 siblings and the average birth position was 1.9. The mediator variables included puberty at age 10 and age at menarche (previously reported). 73% of women in the sample did not have any evidence of puberty at age 10.

Table 1 **Descriptive Statistics of All Variables**

Variable					
Dependent variables:	**Mean**	**SD**	**Range**	**n**	**% Missing**
Age at menarche	12.53	1.165	10-15	4904	45%
Overall fertility	1.79	1.241	0-8	5039	43%
Independent Variables: **Extrinsic mortality** **Parental changes**	**n**	**%**		**Total**	
Separated from mother for a month or longer at age 5				6,322	29%
No	6,005	95%			
Yes	317	5%			
Lived with same parents since birth at age 10				6,591	26%
No	977	15%			
Yes	5,614	85%			
Ever live with only one parent at age 10				6,507	27%
No	5,338	82%			
Yes, still doing so	602	9%			
Yes, in the past	567	9%			
Number of natural parents lived with at age 5				4,595	48%
Both natural parents	4,095	89%			
Natural mother	397	9%			
Natural father	28	1%			

Neither natural parent	75	2%			
Residential moves	**Mean**	**SD**	**Range**	**n**	
Number of residential moves from birth to age 10	1.4	0.731	1-8	4,802	46%
Violence	**Mean**	**SD**	**Range**	**n**	
Worried about violence in their community at age 16 (Derived variable: 1=not worried at all 4=very worried)	1.698	0.648	1-4	3,520	61%
	N	**%**		**Total**	
Force ever used against subject at age 16				3,490	61%
No	3,207	92%			
Yes	283	8%			
Threats ever received at age 16				3,473	61%
No	3,236	93%			
Yes	237	7%			
Seen or taken part in a fight at age 16				3,551	60%
No	1,581	45%			
Saw a fight	1,690	48%			
Participated in a fight	280	8%			
Safeness felt walking alone at age 16				3,548	60%
Very safe	320	9%			
Fairly safe	1,762	50%			
A bit unsafe	1,191	34%			
Very unsafe	275	8%	.		
Disability	**n**	**%**		**Total**	

Disability status at age 10				6,565	26%
No	6,121	93%			
Yes	444	7%			
Siblingship	**Mean**	**SD**	**Range**	**n**	
Number of siblings	1.575	1.165	0-13	6,301	29%
Birth order	1.999	1.188	1-8	2,919	67%
Mediator: Puberty	**n**	**%**		**Total**	
Evidence of puberty at age 10				6,291	29%
No	4,595	73%			
Yes	1,696	27%			
Controls:	**Mean**	**SD**	**Range**	**n**	
Age completed education	16.71	0.995	13-21	4,811	46%
Mother's age at subject's birth	25.98	5.523	14-53	8,262	7%
Father's age at subject's birth	29	6.561	15-70	5,744	36%
Mother's age completed education	15.705	1.706	7-36	8,155	9%
Father's age completed education	15.98	2.373	6-51	7,763	13%
Age of mother at first birth	22.19	4.03	12-47	8,229	8%
	n	**%**		**Total**	
Gross weekly family income in pounds (£)				6,057	32%
under £35	95	2%			
£35 - £49	330	5%			
£50 - £99	1,861	31%			

£100 - £149	2,049	34%		
£150 - £199	961	16%		
£200 - £249	406	7%		
£250 +	355	6%		
Highest education qualification			5,752	35%
No high school diploma	1,426	25%		
Bad GCSE scores	47	1%		
Average GCSE scores	426	7%		
Good GCSE scores	1,878	33%		
1 GCE A level	125	2%		
2 or more GCE A Levels	287	5%		
Associate degree	431	7%		
Bachelor’s degree	993	17%		
Graduate degree	139	2%		
Parent's highest education qualification			6,125	31%
High School Certificate (HSC) or lower	2,480	40%		
Vocational qualification	820	13%		
0 level HSC	1,307	21%		
A level HSC	488	8%		
Registered Nurse	109	2%		
Cert of Education (Primary/secondary teacher)	112	2%		
Bachelor’s degree and higher	809	13%		

Do Early Life Factors Predict Age at Menarche?

The first model was used to address the question of whether the variables predict age at menarche, and subsequently evidence of puberty was added in. The variables that predicted age at menarche were the number of natural parents lived with at age 5 and disability status. Adding evidence of puberty as an independent variable did not substantively change the model.

Lived with both natural parents at age 5 resulted in later age at menarche than not living with either natural parent. Not having a disability also resulted in later age at menarche than having a disability. After adding in whether the cohort member had any evidence of puberty at age 10, both variables remained predictors of age at menarche. Not having evidence of puberty was also a significant predictor of an earlier age at menarche, as expected. Besides disability status and living with both natural parents at age 5, no other variables were significant. This suggests that only those two factors predict age at menarche in this sample.

Table 2 **Do early life factors predict age at menarche?**
Dependent variable: Age at menarche

	Model A			**Model B: Adding evidence of puberty**		
INDEPENDENT VARIABLES:	**B**	**SE**	***p***	**B**	**SE**	***p***
Disability status at age 10 (ref = disability)						
No disability	0.19	0.050	**<.001**	0.196	0.047	**<.001**
Number of siblings	0.026	0.028	0.382	0.007	0.025	0.779
Birth order	0.023	0.051	0.668	0.033	0.042	0.46
PARENTAL CHANGES:						
Separated from mother for a month or longer at age 5 (ref = separated)						
Never separated	-0.167	0.096	0.119	-0.152	0.090	0.126

Lived with same parents since birth at age 10 (ref = yes)						
No	0.157	0.081	0.079	0.116	0.076	0.157
Ever live with only one parent age 10 (ref = yes, in the past)						
No	0.161	0.077	0.053	0.129	0.067	0.068
Yes, still doing so	0.027	0.064	0.677	0.25	0.063	0.695
Number of natural parents living with at age 5 (ref = neither natural parent)						
Both natural parents	0.34	0.097	**0.001**	0.232	0.085	**0.006**
Natural mother	0.244	0.127	0.068	0.16	0.103	0.126
Natural father	0.282	0.207	0.205	0.154	0.187	0.428
VIOLENCE:						
Worried about violence in their community at age 16 (Derived variable: 1=not worried at all 4=very worried)	-0.013	0.028	0.641	-0.014	0.028	0.618
Force ever used against subject at age 16 (ref = force used)						
Force never used	0.201	0.095	0.073	0.15	0.092	0.15
Threats ever received at age 16 (ref = violent threats received)						
No violent threats received	0.115	0.067	0.102	0.098	0.068	0.175
Seen or taken part in a fight at age 16 (ref = participated in a fight)						
Never seen/taken part in a fight	-0.059	0.050	0.245	-0.009	0.053	0.867
Only seen a fight	-0.002	0.066	0.977	0.049	0.070	0.521
Safeness felt walking alone at age 16 (ref = very unsafe)						
Very safe	0.018	0.098	0.856	0.049	0.096	0.621
Fairly safe	0.136	0.111	0.269	0.153	0.105	0.196
A bit unsafe	0.09	0.123	0.494	0.115	0.117	0.366
RESIDENTIAL MOVES:						
Number of residential moves from birth to age 10	0.034	0.025	0.201	0.026	0.027	0.353
Evidence of puberty at age 10 (ref = yes)						
No				0.756	0.041	<**0.001**

Note: This model also controls for the subjects and parents age at completion of education and highest educational qualification, parents age at subjects' birth, mother's age at first birth, and socioeconomic status of the family.

Do Early Life Factors Predict Fertility?

Model two addressed the question of whether all the variables predict fertility or the number of births, using a Poisson regression. The variables that predict fertility were disability status, and number of siblings. Not having a disability resulted in higher fertility than having a disability. Similarly, having more siblings is associated with having high fertility. Again, the results suggest that disability status and number of siblings are the only factors that predicted fertility.

Table 3 Do early life factors predict fertility?

Dependent variable: Fertility

INDEPENDENT VARIABLES:	**B**	**SE**	***p***
Disability status at age 10 (ref = disability)			
No disability	0.076	0.038	**0.049**
Number of siblings	0.055	0.018	**0.014**
Birth order	0.007	0.019	0.715
PARENTAL CHANGES:			
Separated from mother for a month or longer at age 5 (ref = separated)			
Never separated	-0.009	0.041	0.826
Lived with same parents since birth at age 10 (ref = yes)			
No	-0.002	0.047	0.973
Ever live with only one parent age 10 (ref = yes, in the past)			
No	-0.028	0.052	0.6
Yes, still doing so	-0.044	0.054	0.427
Number of natural parents living with at age 5 (ref = neither natural parent)			
Both natural parents	-0.068	0.085	0.436
Natural mother	-0.058	0.085	0502
Natural father	-0.049	0.104	0.643
VIOLENCE:			
Worried about violence in their community at age 16 (Derived variable: 1=not worried at all 4=very worried)	0.02	0.023	0.41
Force ever used against subject at age 16 (ref = force used)			
Force never used	-0.006	0.040	0.888
Threats ever received at age 16 (ref = violent threats received)			
No violent threats received	-0.002	0.044	0.961
Seen or taken part in a fight at age 16 (ref = participated in a fight)			
Never seen/taken part in a fight	-0.035	0.038	0.371
Only seen a fight	-0.039	0.033	0.249
Safeness felt walking alone at age 16 (ref = very unsafe)			
Very safe	-0.022	0.043	0.608
Fairly safe	-0.042	0.039	0.297
A bit unsafe	-0.028	0.048	0.571
RESIDENTIAL MOVES:			
Number of residential moves from birth to age 10	0	0.016	0.989

Note: This model also controls for the subjects and parents age at completion of education and highest educational qualification, parents age at subjects' birth, mother's age at first birth, and socioeconomic status of the family.

Does Menarche or Evidence of Puberty at 10 Years of Age Mediate the Relationship Between Early Life Factors and Fertility?

To examine whether menarche or pubertal evidence mediates the role of early life factors on fertility, I added the age at menarche and evidence of puberty at age 10 variables to the previously described model. Disability status was significant only when evidence of puberty was added in, but number of siblings remained substantively the same. Age at menarche and evidence of puberty were both nonsignificant, suggesting that menarche is not a mediator of the relationship between early life factors and fertility.

Table 4 **Does menarche or evidence of puberty at age 10 mediate the relationship between early life factors and fertility?**

Dependent variable: Fertility

	Model A			**Model B: Adding evidence of puberty**		
INDEPENDENT VARIABLES:	**B**	**SE**	***p***	**B**	**SE**	***p***
Disability status at age 10 (ref = disability)						
No disability	0.076	0.038	0.052	0.076	0.038	**0.049**
Number of siblings	0.056	0.018	**0.011**	0.055	0.018	**0.014**
Birth order	0.007	0.019	0.733	0.007	0.019	0.715
PARENTAL CHANGES:						
Separated from mother for a month or longer at age 5 (ref = separated)						
Never separated	-0.009	0.041	0.819	-0.009	0.041	0.826
Lived with same parents since birth at age 10 (ref = yes)						
No	0	0.047	0.998	-0.002	0.047	0.973
Ever live with only one parent age 10 (ref = yes, in the past)						
No	-0.027	0.052	0.609	-0.025	0.052	0.6
Yes, still doing so	-0.045	0.054	0.423	-0.044	0.0543	0.427
Number of natural parents living with at age 5 (ref = neither natural parent)						
Both natural parents	-0.064	0.086	0.469	-0.068	0.085	0.436
Natural mother	-0.055	0.085	0.524	-0.058	0.085	0.502

Natural father	-0.044	0.106	0.683	-0.049	0.104	0.41
VIOLENCE:						
Worried about violence in their community at age 16 (Derived variable: 1=not worried at all 4=very worried)	0.02	0.234	0.409	0.02	0.023	0.41
Force ever used against subject at age 16 (ref = force used)						
Force never used	-0.004	0.041	0.918	-0.006	0.0403	0.888
Threats ever received at age 16 (ref = violent threats received)						
No violent threats received	-0.002	0.043	0.964	-0.002	0.044	0.961
Seen or taken part in a fight at age 16 (ref = participated in a fight)						
Never seen/taken part in a fight	-0.036	0.038	0.347	-0.035	0.038	0.371
Only seen a fight	-0.041	0.034	0.237	-0.039	0.033	0.249
Safeness felt walking alone at age 16 (ref = very unsafe)						
Very safe	-0.023	0.043	0.584	-0.022	0.043	0.608
Fairly safe	-0.042	0.039	0.295	-0.042	0.039	0.297
A bit unsafe	-0.029	0.048	0.563	-0.028	0.048	0.571
RESIDENTIAL MOVES:						
Number of residential moves from birth to age 10	0	0.015	0.978	0	0.016	0.989
Age at menarche	0	0.015	0.978			
Evidence of puberty at age 10 (ref = yes)						
No				0.024	0.030	0.411

Note: This model also controls for the subjects and parents age at completion of education and highest educational qualification, parents age at subjects' birth, mother's age at first birth, and socioeconomic status of the family.

CHAPTER FOUR: DISCUSSION

My research examined how early life extrinsic mortality cues affects age at menarche and fertility in the 1970 British Cohort Survey. I predicted that higher extrinsic mortality cues would be associated with (1) earlier age at menarche, (2) higher number of offspring, and that (3) menarche would mediate early life factors and fertility. Three statistical models were used to analyze the results.

The only cue of extrinsic mortality I found predicting later age at menarche was the subject living with both natural parents at age 5. Additionally, I did not find any extrinsic mortality cues predicting fertility in this sample. Having a chronic disability predicted both menarche and fertility, with earlier age at menarche and a lower number of offspring. The number of siblings a participant has was also a significant predictor of fertility. Finally, menarche was not a mediator of the relationship between early life factors and fertility.

In this sample, a positive effect was found between number and siblings and reproduction, meaning a higher number of siblings was associated with higher fertility. This is the opposite direction than hypothesized. Thus, instead of resource or nutritional constraint, we may be seeing intergenerational transfers of reproductive knowledge, whereby the fertility of one’s grandmothers and mothers may cue their own fertility.

I also found that family composition does matter and those that are not living with either natural parent does seem to have a faster strategy. However, the literature review shows that context can really matter, and it might matter more in high-income, wealthy contexts than others. Therefore, we may need to reconsider under what conditions we expect to see early life mortality indicators influencing menarche.

The results of the fertility analysis were counter to my predictions. Given the lack of evidence found in this study it may mean that need to reevaluate whether extrinsic mortality cues should predict higher number of offspring or if it's a strategy specifically for early adulthood.

The internal prediction hypothesis states that when an individual's internal state is compromised, like when having a disability, the body's adaptive response may accelerate menarche due to the cue of shortened reproductive lifespan (Rickard et al., 2014). The results of this study support this hypothesis. Previous research by Waynforth (2012), who also evaluated the 1970 British Cohort Survey, found similar results. He demonstrated that chronic disease is associated with earlier first reproduction. However, Waynforth used chronic diseases that increased mortality and only used diseases based on a criteria. This study used an overall variable that asked the participate if they had any disability that interfered with everyday life (Waynforth, 2012).

Having a larger family size results in competition for resources among siblings, even in relatively wealthy contexts (Lawson & Mace, 2008). The findings of number of siblings not being associated with menarche and positively associated fertility, consequently coincides with many non-Western studies (Anderson, 2015; Azcorra, Rodriguez, et al., 2018; Kyweluk et al., 2018; Sheppard et al., 2014; Sohn, 2017). Interestingly, they found similar results, where early life extrinsic mortality factors did not influence age at menarche. Sheppard and colleagues (2014) found that number of siblings had a greater influence on age at menarche than father absence, their preferred measure of extrinsic mortality (Sheppard et al., 2014).

Recently, a study from Yucatan, Mexico, examined the influence of extrinsic mortality cues, as measured by the quality of childhood home construction (measured as childhood living conditions) and father absence, on age at menarche. They found that the child's number of siblings, along with the mother's number of siblings, influenced the child's age at menarche, where higher number of siblings was associated with a later age at menarche. However, living conditions during childhood and father absence, both extrinsic mortality factors, had no effect on age at menarche (Azcorra, Rodriguez, et al., 2018). In a similar study conducted in Cape Town, South Africa, father absence and violence did not predict age at menarche, but did predict age at first sex and age at first reproduction (Anderson, 2015). In the Philippines, nutrition was a significant predictor of menarche, but not extrinsic mortality (sibling death and parental absence). They also found a later age at menarche in risky environments rather than earlier, contrary to expectations (Kyweluk et al., 2018). This could indicate that without nutritional resources an individual may not be able to reach menarche even with high extrinsic mortality factors (Ellis et al., 2009). Finally, Sohn (2017) concluded, based on nonsignificant results of an Indonesian population study and a review of literature, that father absence does not have universal effects on age at menarche (Sohn, 2017). These all suggest that the predicted influence of extrinsic mortality on age at menarche may be very context dependent. We may need to reconsider under what conditions we expect to see early life mortality indicators influencing menarche.

There have not been many studies that look at early extrinsic mortality and number of offspring. One exception is Quinlan (2010) who found that reproductive success (measured as number of children surviving to 10) was associated with extrinsic mortality cues (measured as infant mortality rate at birth and at first birth), where moderate mortality was associated with increased reproductive success, but low mortality and very high mortality was associated with lower reproductive success. Unfortunately, the reproductive success measure makes it hard to separate the effects of child mortality from fertility (does very high mortality mean that women actually produce few children or just that more children died?) (Quinlan, 2010).

Many studies associate fast life history with correlations of early life conditions with earlier menarche or earlier sexual activity in adolescence but are unable to test overall fertility, given the fact that researchers are unable to follow subjects for their full reproductive lifespans. As a result, very few studies look at long-term outcomes. For example, Anderson's (2015) work showed extrinsic mortality did not affect age at menarche but did affect age at first sex and first reproduction (Anderson, 2015). Waynforth (2012) showed chronic disease is associated only with age at first reproduction, but not age at menarche (Waynforth, 2012). In both cases overall fertility was not examined. If there is truly a fast life history strategy we expect consistency across the lifespan, not just in individual's teen years. Simply put, the same early life variables should predict adolescent outcomes like age at menarche and first sexual activity but also translate to later life fertility. This may mean we need to also consider whether this is really a lifelong strategy or a strategy for early adulthood only.

An alternative reason that the results may not show the predicted effects could be other confounding factors that were not tested for. This also may truly be a fast and slow life history but in contexts like the United Kingdom where the fertility rate is less than 2 children per woman, the effects may be masked by not enough variation in the number of children. Consequently, to see effects of a fast or slow life history, a massive sample size would be needed. Likewise, crime rate, a common measure of extrinsic mortality, is fairly low in the United Kingdom.

Child development theory, an alternative to fast-slow life history strategy, proposes that early childhood family experiences alters menarche, first sexual activity, and first reproduction in adolescence, rather than long-term effects on mating and parental investment strategies (fertility). The theory further asserts that pubertal timing is the endpoint of childhood development strategy that extends the period of childhood. The theory argues that a function of early life experience is to coordinate age at menarche based on early socioeconomic environmental cues (Ellis, 2004). My results strongly align with the child development theory rather than the fast-slow life history strategy.

A major limitation of my study was that I did not have the best measures of extrinsic mortality cues. The violence and sex variables were measured during the subject’s adolescence, at age 16, which may have been too late to affect menarcheal age. The dependent variable, age at menarche, may not have been precise enough because it was measured in years instead of months. If the expected effect is in months, then asking subjects their age in years may result in missing the effect.

Due to attrition, multiple imputation was executed as a strategy to deal with missing data. Five imputed datasets were created, which could be an additional limitation because the analysis couldn’t capture if something was systematically different about an individual who has missing data.

Future research should ex amine long-term, longitudinal datasets in the United States where strong effects of extrinsic mortality influencing menarche have been found and look at how that influences later life fertility to repeat this study in another context.

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