Secure infant-mother attachment buffers the effect of early-life stress on age of menarche

A Thesis
SUBMITTED TO THE FACULTY OF
UNIVERSITY OF MINNESOTA
BY

Sooyeon Sung

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF ARTS

Jeffry A. Simpson, Colin G. DeYoung

January 2017

Abstract

Prior research indicates that being reared in stressful environments is associated with earlier onset of menarche in girls. In this research, we examined (a) whether these effects are driven by exposure to certain dimensions of stress (harshness or unpredictability) during the first 5 years of life, and (b) whether the negative effects of stress on the timing of menarche are buffered by secure infant-mother attachment. Results revealed that (a) exposure to greater harshness (but not unpredictability) during the first 5 years of life predicted earlier menarche, and (b) secure infant-mother attachment buffered girls from this effect of harsh environments. By connecting attachment research to its evolutionary foundations, these results illuminate how environmental stressors and relationships early in life jointly affect pubertal timing.

Table of Contents

List of Tables

List of Figures

Decades of theory and research converge on the conclusion that exposure to stressful environments in childhood accelerates pubertal development in girls as measured by onset of menarche (e.g., Belsky et al., 2007; Belsky, Steinberg, Houts, & Halpern-Felsher, 2010; Deardorff et al., 2011; Ellis & Essex, 2007; Ellis & Garber, 2000; Moffitt, Caspi, Belsky, & Silva, 1992; Surbey, 1990; for reviews, see Ellis, 2004, and Belsky, 2012). Although age at menarche is heritable (e.g., Belsky, 2000; Rowe, 2000), studies incorporating genetic controls have confirmed that the association between early-life stress and age at menarche is robust (e.g., Belsky, Houts, & Fearon, 2010; Tither & Ellis, 2008).

Many studies, however, have operationalized early-life stress broadly at the cost of specifying the types of stress that may be more or less important in predicting menarcheal timing. Drawing on Belsky, Steinberg, and Draper's (1991; Belsky, 1997) evolutionary theory of socialization and Ellis, Figueredo, Brumbach, and Schlomer's (2009) life history model of environmental stress, we address two important questions about the connection between stress and reproductive maturity: Do specific types of environmental stress encountered early in life uniquely predict age of menarche? Are the effects of environmental stress on menarcheal age buffered by the security of the infant-mother attachment relationship?

Life-History Theory, Stress, and Age of Menarche

Life-history theory explains how organisms allocate their inherently limited resources to optimize reproductive fitness (Kaplan & Gangestad, 2005; Stearns, 1992). According to this evolutionary biological theory, developing organisms face a fundamental trade-off between allocating resources to somatic effort (i.e., growth and maintenance) versus reproductive effort (i.e., sexual maturation and mating). Central to life-history thinking is the premise that the specific strategy an individual adopts depends in part on his or her early rearing environment (Belsky et al., 1991; Chisholm, 1999). In environments that are harsh or unpredictable (or both), for example, faster strategies that prioritize greater reproductive effort increase the likelihood of reproducing before death. However, when harshness or unpredictability (or both) are low (or can be managed), slower strategies that prioritize investment in somatic effort are more adaptive (Belsky et al., 1991; Ellis et al., 2009). Neither fast nor slow strategies are inherently better. Instead, the evolutionary benefit of a given strategy depends on the environment in which an individual develops (Belsky, 1997; Belsky et al., 1991; Caudell & Quinlan, 2012; Kuzawa, McDade, Adair, & Lee, 2010; Simpson & Belsky, 2008, in press).

Belsky et al. (1991) were the first to specify how life-history strategies should unfold across the life span. They advanced a unique prediction about the effects of childhood stress on development: Exposure to greater childhood stress (e.g., inadequate resources, an absent father, insensitive or harsh parenting, marital conflict) should accelerate pubertal maturation. Considerable evidence consistent with this proposition has emerged for females, particularly with regard to age of menarche (Belsky, 2012). For example, greater family disruption (especially fathers' social deviance) predicts earlier age of menarche (Tither & Ellis, 2008). Maltreated girls reach pubertal maturity 8 months earlier than girls who are not maltreated (Costello, Sung, Worthman, & Angold, 2007), and earlier harsh maternal care forecasts earlier menarche (Belsky et al., 2007; Belsky, Steinberg, et al., 2010). Taking advantage of an existing situation, Pesonen et al. (2008) observed that young Helsinki girls who were evacuated from their homeland during World War II and sent to other countries reached menarche at a younger age (and also bore more children by late adulthood) compared with young girls who remained at home and avoided the trauma of separation from their families.

In modern Western societies, in which nutritional deprivation is not as severe as in underdeveloped countries, lower socioeconomic status accelerates pubertal maturation (Ellis, 2004). When environments are harsh (because of non-food-related factors such as social competition) but calories are sufficient, menarche should and does occur earlier in life (see Ellis et al., 2009). The current research extends prior work by moving beyond the assessment of general stress levels or very specific stressors to examine two fundamental dimensions of environmental variation that many living organisms encounter in the service of fitness goals.

Environmental Stress Dimensions: Harshness and Unpredictability

Ellis et al. (2009) proposed that the development of life-history strategies is regulated by two environmental dimensions: harshness and unpredictability. Harshness refers to the mean level of extrinsic mortality and morbidity in a population, which in modern populations is closely tied to socioeconomic status (Belsky, Schlomer, & Ellis, 2012; Chen & Miller, 2012; Simpson, Griskevicius, Kuo, Sung, & Collins, 2012). Unpredictability refers to fluctuations in environmental conditions; in modern populations, this relates to frequent residence changes and family instability (i.e., having family members, especially paternal figures, move in and out of the home).

According to Ellis et al. (2009), exposure to harsh or unpredictable environments early in life should have unique effects on shaping life-history strategies, including accelerating pubertal timing. Recent empirical evidence about the unique effects of harshness and unpredictability on pubertal and reproductive timing, however, is mixed. Several longitudinal studies indicate that exposure to harsher or more unpredictable environments (or both) early in life does uniquely forecast fast-strategy outcomes in adolescence, such as greater delinquency and more sexual partners (e.g., Belsky et al., 2012; Brumbach, Figueredo, & Ellis, 2009; Simpson et al., 2012); some other studies find that unpredictability, as measured specifically by the absence of the father, is not uniquely associated with age of menarche (Ryan, 2015) or age at first sex (Carlson, Mendle, & Harden, 2014). Thus, the current study sought to test the unique effects of environmental harshness and unpredictability.

Moderating Effects of Early Attachment Security

Is it inevitable that exposure to stress early in life accelerates reproductive development? According to both attachment theory (Bowlby, 1973, 1988) and life-history approaches (e.g., Belsky et al., 1991; Del Giudice, 2009), the attachment bond reflects a more proximal developmental process than many distal sources of stress (e.g., poverty, absent father). The attachment bond, therefore, may be able to override the distal sources of stress, thereby buffering secure girls exposed to high levels of stress early in life and preventing them from undergoing earlier menarche.

Children develop secure attachment relationships with their primary caregiver (usually the mother) primarily in reaction to receiving responsive, situationally appropriate parental care. Children are also more likely to be secure if their caregivers have good mental health, if their parents have a happy relationship, and if sufficient social support is available (Belsky & Fearon, 2008). Because of these factors, securely attached children have greater confidence (compared with insecurely attached children) that their caregivers will provide safety, comfort, and emotional reassurance, especially in challenging or stressful situations (Ainsworth, Blehar, Waters, & Wall, 1978). Because they have received better and more consistent care, securely attached children usually adopt slower reproductive strategies across the life span (Belsky et al., 1991; Simpson & Belsky, 2008, in press). Secure children appear to learn that their caregivers can be reliably counted on for comfort and support when stressed. Accordingly, girls with insecure attachment histories experienced menarche at a younger age than secure girls (Belsky, Houts, & Fearon, 2010).

The current research extends this prior work, which has documented a main effect of attachment, to determine whether attachment moderates the effect of stress on pubertal timing. According to the model from Belsky et al. (1991), the nature and quality of the parent-child attachment relationship early in life should moderate the effect of stress on reproductive strategies and pubertal timing. Consistent with this claim, evidence from recent studies has shown that high-quality parenting protects individuals against the adverse effects of early-life stress on pro-inflammatory responses (Chen, Miller, Kobor, & Cole, 2010) and externalizing behavior problems (Skopp, McDonald, Jouriles, & Rosenfield, 2007). Thus, we propose that exposure to stress may differentially affect secure and insecure children, potentially buffering secure children from accelerated reproductive maturity.

The Current Longitudinal Study

Drawing on data from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) Study of Early Child Care and Youth Development (SECCYD), we address two questions: (a) Does exposure to harsher or more unpredictable environments (or both) during the first 5 years of life uniquely predict earlier onset of menarche in girls (controlling for their mother's age of menarche)? (b) If so, are secure children protected from this stress-accelerating effect? Although it remains unclear which environmental dimension should forecast age of menarche, we predicted that girls with secure attachment histories would be protected from the adverse effects of stress.

Method

Participants

The NICHD Study of Early Child Care and Youth Development (SECCYD) recruited 1,364 families through hospital visits shortly after the birth of each child in 1991 at 10 U.S. locations. For a detailed description of recruitment procedures and sample, see the NICHD Early Child Care Research Network (2001) and fsehttp://www.icpsr.umich.edu/icpsrweb/ICPSR/series/00233.

The analysis sample included 492 females with data on age of menarche. Racial-ethnically, 398 were White (80.9%), 60 were Black (12.2%), 10 were Asian (2.0%), and 24 reported another ethnicity (4.9%). Compared to all other sample members, analysis-sample members were more likely to be securely attached at 15 months of age, t (1189) =

-2.50, $p = .013$, came from higher-income families (i.e., income-to-needs ratio), t (1353) = -2.72, $p = .007$, and experienced fewer paternal transitions during childhood, t (1340) = 2.34, $p = .020$, but did not differ on residential or parental job changes.

Measures

Environmental harshness. Following Belsky et al. (2012) and Simpson et al. (2012), environmental harshness was indexed by the economic resources of each family, which is a prime indicator of socioeconomic status. The economic resources of families were assessed using the income-to-needs ratio, an index of family's income as a proportion of the federal poverty line for a family of that size. Family income was divided by the poverty threshold, adjusted for total family size. Thus, a ratio of 1 indicates that family income equals the federal poverty threshold for a family of that size. In 1991 (the year that participants were born), the poverty threshold for a family of four was an annual income of $13,812. A higher income-to-needs ratio indicates greater financial resources *per person* in the household. During each participant's (each child's) first 5 years of life, the income-to-needs ratio was assessed repeatedly (when participants were 1, 6, 15, 24, 36, 54, and 60 months of age), based on his/her mother's detailed reports of family finances.

To create an index of early environmental harshness during the first 5 years of life, income-to-needs ratios were averaged over time ($\alpha = .95$). They ranged from .17 to 23.79 ($M = 3.63$, $SD = 2.73$), with a score of 1 reflecting the federal poverty line. Since high income-to-needs ratios indicate less harsh environments, the index was reversed scored (such that higher values = greater resources).

Environmental unpredictability. Also consistent with past research (e.g., Belsky et al., 2012; Simpson et al., 2012), environmental unpredictability across the first 5 years of life was assessed using three measures (see Belsky et al., 2012, and the Supplemental Material available online): (1) *paternal transitions*—the number of changes in the male parental figure within the home, based on face-to-face or telephone interviews about household composition when children were 1, 3, 6, 9, 12, 15, 18, 21, 24, 30, 33, 36, 42, 46, 50, 54, and 60 months old; (2) *household moves*—changes in residence, based on whether and when families relocated during the first 5 years of each child's life; and (3) *parental employment*—the number of changes in the mother's and the father's or boyfriend's employment during each child's first 5 years, based on reports at the ages mentioned above. To create a scale of early environmental unpredictability, the three scores were standardized and averaged ($\alpha = .54$). The unpredictability scale ranged from -1.00 to 3.39 ($M = -.08$, $SD = .68$).

Infant attachment. When children were 15 months old, infant-mother attachment was assessed using the Strange Situation procedure (Ainsworth et al., 1978). Infant-mother attachment relationships were classified as secure or insecure based on how each infant responded to his or her mother following a series of brief, stressful separations. Upon reunion, secure infants usually approach their mothers, are soothed by them, calm down quickly, and then resume normal activity (e.g., play, exploration). Insecure infants either do not approach their mothers or display anger toward them, never fully calming down and not resuming normal activity during the assessment. Among our participants (children), 127 (26.8%) were classified as insecure at 15 months, and 347 participants (73.2%) were classified as secure.

Age of menarche. Age of menarche was reported between 9-15 years of age. Some participants reported it at more than one assessment, and others reported it just once. When age of menarche was reported multiple times, the reports were averaged. Age of menarche ranged from 9.03 to 15.50 years (*M* = 12.40 years, *SD* = 1.13).

Maternal age of menarche. Each participant's mother also reported her age of menarche, which was used to partially control for shared genetic effects that could account for her child's menarcheal timing. Maternal age of menarche ranged from 9.00 to 18.00 years (*M* = 12.71 years, *SD* = 1.46).

Birth weight. The mother of each participant was interviewed within 24 hours after delivery and reported her baby's birth weight, which ranged from 2.00 to 5.34 kg (*M* = 3.43 kg, *SD* = .49).

Results

Descriptive Statistics

Table 1 presents relations between all of the variables.

Table 1

Correlations between variables

	1	2	3	4	5	6	7
1. Ethnicity	–						
2. Attachment security	.07	–					
3. Maternal age of menarche	$.12^{*}$	.07	–				
4. Birth weight	$.16^{***}$	.07	.01	–			
5. Harshness	$-.38^{***}$	$-.10^{*}$	-.07	-.07	–		
6. Unpredictability	$-.18^{***}$	-.01	.02	-.09	$.38^{***}$	–	
7. Age of menarche	$.20^{***}$	$.14^{**}$	$.38^{***}$	.06	$-.23^{***}$	-.07	–

*Note. N*s range from 456-492. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Ethnicity, which was coded 0 (Non-White) or 1 (White), was significantly associated with most of the variables. Compared to non-whites, White children were heavier at birth, experienced less harsh and unpredictable environments and had their first menstrual cycle later.

Greater harshness (lower income-to-needs ratio) was associated with greater unpredictability and earlier age of menarche. Girls classified as secure at 15 months experienced menarche later (as reported by Belsky et al., 2010). Maternal age of menarche was positively associated with girls' age of menarche, but not with girls' environmental harshness, unpredictability, or attachment security. Birth weight was not significantly related to any of the variables.

Tests of Hypotheses

To test (a) whether harshness and/or unpredictability uniquely predicted age of menarche, and (b) whether infant-mother attachment security moderated these effects, we conducted a hierarchical regression analysis. The main effects of environmental harshness, unpredictability, and attachment security along with 3 covariates (maternal age of menarche, ethnicity [White or non-White], and birth weight) were entered in the first block, and all 2-way interactions involving the first three predictors in the second. Listwise deletion was used to deal with missing values since Little's MCAR test indicated that data were missing completely at random (MACR), $\chi^2(3) = 5.18$, $p = .16$. A square root transformation was applied to the environmental harshness and unpredictability measures given their positively skewed distributions.

As shown in Table 2, greater environmental harshness (i.e., lower income-to-needs ratio) (β = -.26, p = .003), but *not* unpredictability (β = -.10, p > .25), uniquely predicted earlier age of menarche. Additionally, and as previously reported (Belsky et al., 2010), being securely attached at 15 months also forecasted later menarche (β = .10, p = .023).

Table 2

Hierarchical Regression

Predictor Variables:	*B*	*SE*	*β*	95% *CI*	ΔR^2
Step 1					$.21^{***}$
Constant	11.95	.15		[11.67,12.24]	
Ethnicity	.32	.14	$.11^{*}$	[.05, .59]	
Maternal age of menarche	.28	.03	$.36^{***}$	[.22, .35]	
Birth weight	.09	.10	.04	[-.11, .29]	
Attachment security	.26	.11	$.10^{*}$	[.05, .48]	
Harshness	-.26	.09	$-.15^{**}$	[-.43, -.09]	
Unpredictability	.03	.08	.02	[-.16, .18]	
Step 2					$.01^{*}$
Constant	11.91	.15		[11.62,12.21]	
Ethnicity	.35	.14	$.12^{*}$	[.08,.62]	
Maternal age of menarche	.28	.03	$.36^{***}$	[.22, .35]	
Birth weight	.08	.10	.04	[-.12, .28]	
Attachment security	.25	.11	$.10^{*}$	[.04, .47]	
Harshness	-.46	.15	$-.26^{**}$	[-.76, -.16]	
Unpredictability	-.16	.15	-.10	[-.45, .14]	
Harshness × Attachment	.35	.18	$.16^{*}$	[.00, .70]	
Unpredictability × Attachment	.18	.17	.09	[-.14, .51]	
Harshness × Unpredictability	.18	.11	.08	[-.04, .41]	

Note. N = 456. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Notably, girls who were exposed to harsher early-life environments but who were securely attached to their mothers were buffered from accelerated reproductive development (see Figure 1). Specifically, the harshness by attachment interaction was significant (β = .16, p = .048). Greater harshness predicted earlier menarche, but only for girls who were insecurely attached to their mothers at 15 months of age, $b = -.51$, $SE = .15$, $p = .003$, and *not* for girls who were securely attached, $b = -.14$, $SE = .11$, $p > .25$

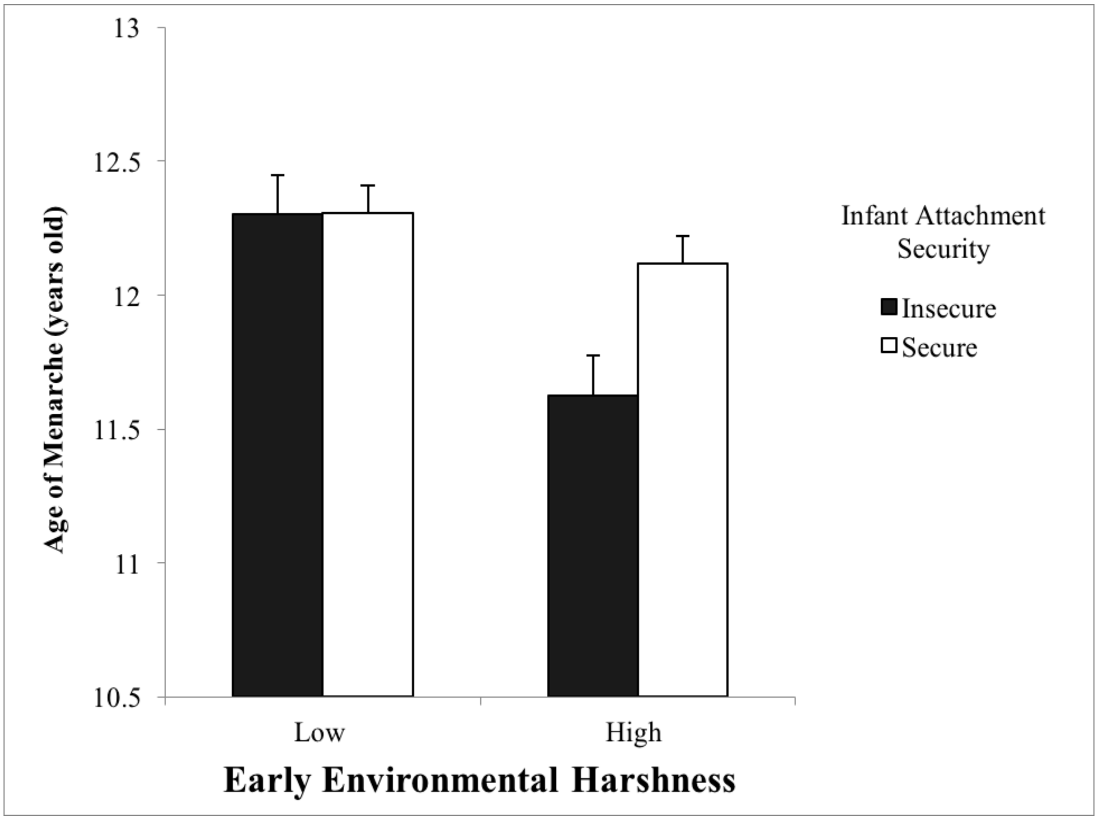

Figure 1. The moderating effect of infant-mother attachment security at 15 months on the effect of early environmental harshness on age of menarche.

Importantly, all of the effects presented here remained significant when we partially controlled for the shared genes between mothers and their daughters (indexed by mothers' age of menarche), which independently and positively predicted the timing of menarche.

Additional Analyses

We also conducted a series of additional analyses to examine alternative models and other possible predictions.

The effect of male presence in the home. Although the paternal transitions item was one of the items in our unpredictability measure, we also treated this variable as an independent control variable in additional analyses. On the basis of each mother's reports of household composition when her child was 1, 3, 6, 9, 12, 15, 18, 21, 24, 30, 33, 36, 42, 46, 50, 54, and 60 months old, we determined whether the person identified as the child's biological father (or the mother's male partner) was present (coded 1) or absent (coded 0) at each assessment period. We then created a "male presence" variable by averaging each participant's scores over all the assessment time-points. A composite score of 1 indicated that a male partner was present at *all* assessment time-points, whereas a composite score of 0 indicated that a male partner was never present in the home. The mean of this measure was .85 (*SD* = .31). For 358 participants (72.8% of the sample), a male partner was present in the home at *all* assessment time-points; for 35 participants (7.1% of the sample), a male partner was never present in the home. Thus, approximately 80% of participants in the sample never experienced any paternal transitions. This may have attenuated potential unpredictability effects.

The male presence measure was significantly correlated with most of the variables we examined (see Table 3). Modeling male presence as a control variable in the regression model did *not* change the general pattern of findings (see Table 4). Ethnicity, maternal age of menarche, attachment security, and environmental harshness still significantly predicted age of menarche. In addition, the key harshness by attachment security interaction effect remained. In other words, exposure to greater harshness early in life continued to predict earlier age of menarche in girls who were insecurely attached to their mothers at 15 months of age, $b = -.45$, $SE = .16$, $p < .006$, but *not* in girls who were securely attached at 15 months, $b = -.11$, $SE = .10$, $p > .25$, although the overall interaction became marginally significant, $\beta = .16$, $p = .059$.

Table 3

Correlations between male presence and the other variables

	Male Presence
Ethnicity	$.50^{***}$
Attachment security	$.09^{*}$
Maternal age of menarche	.04
Birth weight	$.09^{*}$
Harshness	$-.51^{***}$
Unpredictability	$-.35^{***}$
Age of menarche	$.16^{***}$

Note. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 4

Regression model including male presence as a control variable

Predictor Variables:	*B*	*SE*	*β*	95% *CI*
Constant	11.88	.20		[11.48,12.28]
Ethnicity	.34	.15	$.12^{*}$	[.06,.63]
Maternal age of menarche	.28	.03	$.36^{***}$	[.22, .35]
Birth weight	.08	.10	.04	[-.12, .28]
Male presence	.05	.21	.01	[-.36, .47]
Attachment security	.25	.11	$.10^{*}$	[.04, .46]
Harshness	-.45	.16	$-.25^{**}$	[-.77, -.13]
Unpredictability	-.16	.15	-.10	[-.45, .13]
Harshness × Attachment	.34	.18	$.16^{\dagger}$	[-.01, .70]

Unpredictability × Attachment	.19	.17	.10	[-.14, .52]
Harshness × Unpredictability	.19	.11	.08	[-.04, .41]

Note. †p = .059. * $p < .05$. ** $p < .01$. *** $p < .001$

An alternative explanation involving maternal sensitivity. Whether children develop secure or insecure attachment relationships with their parents depends partly on the amount and quality of responsive care they have received from their parents (van IJzendoorn, 1995). The security of attachment relationships, however, also depends on various transactional processes that occur between the parent and child (Carlson et al., 2004), meaning that the amount and quality of parental care is only one predictor of attachment security. Attachment security reflects the operation of a well-functioning stress regulation/coping system, which is partly facilitated by good, sensitive parental care. This explains why attachment security should moderate the connection between exposure to early environmental stress and age of menarche in girls. Nonetheless, the quality and sensitivity of parenting received remains another possible mediator of this link. For this reason, we conducted additional analyses to test for the possible moderating effects of the quality of sensitive care that each child received from her mother early in life.

At various points during development, the quality of social interactions between each mother and her child (i.e., maternal sensitivity) was rated from videotapes of semi-structured tasks involving each mother and her child. These videotaped interactions were conducted in the home at 6 and 15 months and in the lab at 24, 36, and 54 months. At 6, 15, and 24 months, coders rated maternal behavior on three dimensions: (a) sensitivity/responsiveness to the child, (b) intrusive behavior directed at the child (reverse-coded), and (c) positive regard for the child. These ratings were then summed across these time-periods. At 36 and 54 months, maternal behavior was rated on three dimensions: (a) supportive presence displayed toward the child, (b) respect for the child's autonomy, and (c) hostility directed at the child (reverse-coded). These ratings were also summed across these time-periods. To conduct the current analyses, the maternal behavior scores from all five assessment periods were then standardized and averaged to create a composite measure of maternal sensitivity across the first 5 years of life ($M = .00$, $SD = .74$).

The maternal sensitivity composite was significantly correlated with almost all of the variables in the study (Table 5). To test whether maternal sensitivity was (1) a possible confounding variable, or (2) had moderating effects on the relation between early harshness and age of menarche, we conducted a hierarchical regression analysis. As shown in Table 6, maternal sensitivity did not significantly predict age of menarche (controlling for other variables), $\beta = -.01$, $p > .25$, and it did not moderate the link between early harshness and age of menarche, $\beta = -.04$, $p > .25$. Instead, the moderating effect of attachment security on the relation between harshness and age of menarche remained statistically significant, $\beta = .18$, $p = .038$, even after maternal sensitivity was included in the model.

Table 5

Correlations between maternal sensitivity and other variables

Variables:	Maternal Sensitivity
Ethnicity	$.40^{***}$

Attachment security	.14**
Maternal age of menarche	.07
Birth weight	.13**
Harshness	-.45***
Unpredictability	-.30***
Age of menarche	.16***

Note. * $p < .05$. ** $p < .01$. *** $p < .001$.

Table 6

Hierarchical Regression Including Maternal Sensitivity

Predictor Variables:	*B*	*SE*	*β*	95% *CI*	*ΔR*²
Step 1					.23***
Constant	11.91	.15		[11.60,12.21]	
Ethnicity	.36	.14	.12*	[.08, .64]	
Maternal age of menarche	.28	.03	.36***	[.22, .35]	
Birth weight	.08	.10	.04	[-.11, .28]	
Attachment security	.25	.11	.10*	[.04, .47]	
Maternal sensitivity	-.02	.08	-.01	[-.18, .15]	
Harshness	-.47	.16	-.26**	[-.78, -.16]	
Unpredictability	-.16	.15	-.10	[-.45, .13]	
Harshness × Attachment	.35	.18	.16*	[.00, .70]	
Unpredictability × Attachment	.18	.17	.10	[-.15, .51]	
Harshness × Unpredictability	.18	.11	.08	[-.04, .41]	
Step 2					.01*
Constant	11.85	.16		[11.54,12.17]	
Ethnicity	.39	.15	.13**	[.10, .67]	
Maternal age of menarche	.28	.03	.36***	[.21, .35]	
Birth weight	.08	.10	.03	[-.12, .28]	
Attachment security	.27	.11	.10*	[.05, .48]	
Maternal sensitivity	.02	.09	.01	[-.15, .19]	
Harshness	-.48	.16	-.27**	[-.79, -.17]	
Unpredictability	-.16	.15	-.10	[-.46, .14]	
Harshness × Attachment	.38	.18	.18*	[.02, .75]	
Unpredictability × Attachment	.19	.17	.10	[-.15, .52]	
Harshness × Unpredictability	.08	.13	.03	[-.16, .33]	
Harshness × Maternal sensitivity	-.10	.12	-.04	[-.34, .14]	
Unpredictability × M. sensitivity	-.13	.10	-.06	[-.32, .07]	

Note. * $p < .05$. ** $p < .01$. *** $p < .001$.

The moderating effect of attachment security using latent measures of harshness and unpredictability. In their 2012 paper, Belsky et al. modeled harshness and unpredictability as latent variables, whereas we treated them as manifest variables in the current study. After using a square root transformation on our harshness and unpredictability measures, the correlation between the two as unit-weighted composites was .38. The correlation between harshness and unpredictability as latent measures, however, was .51. Compared to the .43 correlation between the latent measures of harshness and unpredictability reported in Belsky et al. (2012), our latent correlation of .51 might be attenuating some of our effects. We tested the moderating effect of attachment security using multi-group structural equation modeling to compare insecure vs. secure groups, with harshness and unpredictability measured as latent variables.

Compared to the model in which all parameters were constrained to be equal across the groups, $\chi^2(152) = 371.18$, $p < .001$, the model in which the path coefficient from harshness to age of menarche was freely estimated produced a fit that was significantly better, $\chi^2(151) = 367.14$, $p < .001$, $\Delta\chi^2(1) = 4.05$, $p = .044$. Within the insecure group, harshness significantly predicted age of menarche, $\beta = -.33$, $p < .001$, whereas within the secure group, the association was not significant, $\beta = -.12$, $p = .070$. This finding confirms that attachment security moderated the relation between early harshness and age of menarche. However, attachment security also moderated the connection between unpredictability and age of menarche, as revealed by the fact that there was a significantly better fit for the model in which the path from unpredictability to age of menarche was freely estimated, $\chi^2(151) = 366.14$, $p < .001$, compared to the fully constrained model, $\chi^2(152) = 371.18$, $p < .001$, $\Delta\chi^2(1) = 5.04$, $p = .028$. The associations between unpredictability and age of menarche in both groups, however, were *not* statistically significant ($\beta = -.19$, $p = .161$ and $\beta = .12$, $p = .146$ for the insecure and secure groups, respectively). Moreover, both the factor loadings on the latent measures of harshness and unpredictability and the correlations between the predictors did not differ across the groups, as indicated by a non-significant chi-square test, $\Delta\chi^2(18) = 27.63$, $p = .068$, which compared the model in which all factor loadings and correlations were constrained to be equal across the two groups, $\chi^2(150) = 365.73$, $p < .001$, to the model in which they were freely estimated, $\chi^2(132) = 338.11$, $p < .001$.

Testing attachment security as a mediator between harshness and age of menarche.

The possible mediating effect of attachment security linking harshness and age of menarche was also tested. Using the same NICHD SECCYD data set, Belsky et al. (2012) tested a mediation model treating maternal sensitivity as a mediator. From a methodological standpoint, using income-to-needs ratio assessed after the participants (children) were 15 months old (precisely when attachment security was assessed) was not a valid way to test the mediation model. Thus, only harshness measures (i.e., income-to-needs ratio) assessed at 1, 6, and 15 months of age were used to test the mediation model. Given the non-significant association between unpredictability and age of menarche, $\beta = .07$, $p > .25$, the mediating effect of attachment security on unpredictability and age of menarche was not tested, and unpredictability was included as a control variable. Structural Equation Modeling (SEM) was used to test the mediation model.

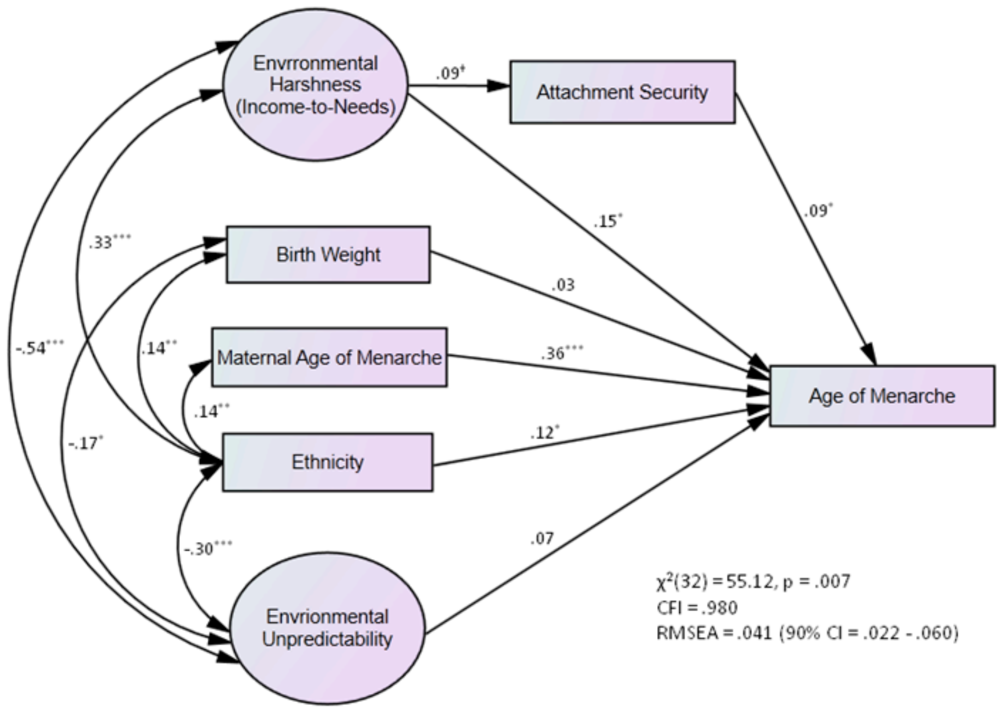

Figure 2. The mediation model. CFI = comparative fit index, RMSEA = root-mean-square error of approximation. † $p < .10$ * $p < .05$. ** $p < .01$. *** $p < .001$.

The mediation model that was tested is shown in Figure 2 along with the standardized coefficients. All possible correlations between the predictor variables were included in the model, but only significant ones are reported. Consistent with the results from the multiple regression analyses that tested the moderation effect of attachment security, maternal age of menarche ($\beta = .36$) and ethnicity ($\beta = .12$) both significantly predicted age of menarche. The mediating effect of attachment security was attenuated by the significant direct effect of harshness predicting age of menarche, $\beta = .15$, $p = .023$, which remained reliable when the indirect path through attachment security was included. We tested the significance of the indirect effect using a bootstrapping procedure with

1000 random samples. The results indicated that the indirect effect was not significant, $b = .016$, $SE = .013$, 95% CI = -.001 - .052.

Discussion

Drawing on Belsky et al.'s (1991; Belsky, 1997) evolutionary theory of socialization and Ellis and colleagues' (2009) life history model of environmental stress, this study addressed two questions: (1) Do specific dimensions of environmental stress—harshness and/or unpredictability—uniquely predict the earlier onset of menarche in girls? And (2) Does secure infant-mother attachment protect girls from the developmentally accelerating effect of stress?

Regarding question 1, this is the first study to show that early-life harshness—but not unpredictability—uniquely predicted the timing of menarche in girls in the theoretically-anticipated manner, with greater stress stemming from a harsh environment leading to accelerated reproductive development. It should be noted, however, that the SECCYD sample has few truly impoverished families, and Ellis et al.'s model acknowledges that different life history outcomes may emerge depending on the absolute level of stress to which children are exposed early in life. Future research is needed to test whether in samples containing more families that have experienced extreme unpredictability, results might be different.

Regarding question 2, having a secure infant-mother attachment buffered girls from accelerated reproductive development, even when they grew up in a family with limited economic resources. This finding extends previous research chronicling the stress-protective effect of having a supportive parent-child relationship (see Belsky et al., 1991, 2010; Chen & Miller, 2012). In so doing, it also suggests that supportive proximal relationship processes might be able to over-ride more distal, stressful environments.

Despite its longitudinal design, reasonably diverse sample, and good measures collected at different points of development, the current research has some limitations. First, our predicted early environmental harshness by infant-mother attachment security interaction effect, although statistically significant, is not large. It needs to be replicated in future longitudinal samples.

Second, our measures of harshness and unpredictability assess these constructs indirectly. We measured them this way to be consistent with prior research (e.g., Belsky, Houts & Fearon, 2010; Belsky et al., 2012; Simpson et al., 2012) in order to facilitate comparisons of findings with earlier studies. In future research, however, different possibilities for operationalizing both constructs should also be examined using methods that are consistent with the way in which harshness and unpredictability have been conceptualized theoretically.

Third, some prior studies have found that harshness and unpredictability both forecast certain life-history outcomes in adolescents (e.g., sexual behavior in girls; Belsky et al., 2012), whereas others have found that unpredictability alone predicts certain life-history outcomes in young adults (e.g., sexual behavior, deviance, and aggression in both sexes; Simpson et al., 2012). These different outcomes might be partly attributable to the demographic characteristics of the samples being studied (e.g., higher vs. lower SES samples), sampling error, or the indirect measurement of harshness and unpredictability. Future research should address and rectify these limitations.

Finally, in relation to the aforementioned demographic characteristics of the sample, the effects of unpredictability may have been obscured by the absence of more impoverished families experiencing extreme household chaos, only some factors that might impact menarche were examined, and the findings may have been different if other indices of reproductive maturation were studied. Future research is needed to address these limitations.

In conclusion, this research lies at the intersection of and integrates two major theories, attachment theory (Bowlby, 1973, 1988) and evolutionary models grounded in life history theory (Belsky et al., 1991; Ellis et al., 2009). It connects attachment theory to its original theoretical roots in evolutionary biology, a foundation largely neglected over the past four decades (Belsky, 1997; Simpson & Belsky, 2016), by showing how early attachment is related to reproductive development, not just psychological and behavioral development. More specifically, it illuminates conditions under which exposure to harsh environments in infancy does—and does not—accelerate female reproductive development.

References

Ainsworth, M. S., Blehar, M. C., Waters, E., & Wall, S. (1978). *Patterns of attachment: A psychological study of the strange situation*. Hillsdale, NJ: Erlbaum.

Belsky, J. (1997). Attachment, mating, and parenting: An evolutionary interpretation. *Human Nature*, *8*, 361-381.

Belsky, J. (2000). Conditional and alternative reproductive strategies: Individual differences in susceptibility to rearing experiences. In J. Rodgers, D. Rowe, & W. Miller (Eds.), *Genetic influences on human fertility and sexuality: Theoretical and empirical contributions from the biological and behavioral sciences* (pp. 127-146). Boston, MA: Kluwer.

Belsky, J. (2012). The development of human reproductive strategies: Progress and prospects. *Current Directions in Psychological Science, 21*, 310-316.

Belsky, J., & Fearon, R. M. P. (2008). Precurors of attachment security. In *Handbook of attachment: Theory, research, and clinical applications* (2nd ed., pp. 295-316). New York: Guilford.

Belsky, J., Houts, R. M., & Fearon, R. (2010). Infant attachment security and the timing of puberty: Testing an evolutionary hypothesis. *Psychological Science, 21*(9), 1195-1201. doi: 10.1177/0956797610379867

Belsky, J., Schlomer, G. L., & Ellis, B. J. (2012). Beyond cumulative risk: Distinguishing harshness and unpredictability as determinants of parenting and early life history strategy. *Developmental Psychology, 48*(3), 662-673. doi: 10.1037/a0024454

Belsky, J., Steinberg, L., & Draper, P. (1991). Childhood experience, interpersonal development, and reproductive strategy: An evolutionary theory of socialization. *Child Development, 62*(4), 647-670. doi: 10.2307/1131166

Belsky, J., Steinberg, L., Houts, R. M., & Halpern-Felsher, B. L. (2010). The development of reproductive strategy in females: Early maternal harshness -> earlier menarche -> increased sexual risk taking. *Developmental Psychology, 46*(1), 120-128. doi: 10.1037/a0015549

Belsky, J., Steinberg, L. D., Houts, R. M., Friedman, S. L., DeHart, G., Cauffman, E., . . . Susman, E. (2007). Family rearing antecedents of pubertal timing. *Child Development, 78*(4), 1302-1321. doi: 10.1111/j.1467-8624.2007.01067.x

Bowlby, J. (1973). *Attachment and Loss: Vol. 2 Loss: Sadness and Depression.* New York: Basic Books.

Bowlby, J. (1988). *A secure base.* New York: Basic Books.

Brumbach, B. H., Figueredo, A. J., & Ellis, B. J. (2009). Effects of harsh and unpredictable environments in adolescence on development of life history strategies: A longitudinal test of an evolutionary model. *Human Nature, 20*(1), 25-51. doi: 10.1007/s12110-009-9059-3

Carlson, M. D., Mendle, J., & Harden, K. P. (2014). Early adverse environments and genetic influences on age at first sex: Evidence for gene× environment interaction. *Developmental Psychology, 50*(5), 1532.

Carlson, E. A., Sroufe, L. A., & Egeland, B. (2004). The construction of experience: A longitudinal study of representation and behavior. *Child Development, 75*(1), 66-83.

Caudell, M. A., & Quinlan, R. J. (2012). Resource availability, mortality, and fertility: A path analytic approach to global life-history variation. *Human Biology, 84*(2), 101-125.

Chen, E., & Miller, G. E. (2012). "Shift-and-persist" strategies: Why low socioeconomic status isn't always bad for health. *Perspectives on Psychological Science, 7(2),* 135-158. doi: 10.1177/1745691612436694

Chen, E., Miller, G.E., Kobor, M.S., & Cole, S.W. (2010). Maternal warmth buffers the effects of low early-life socioeconomic status on pro-inflammatory signaling in adulthood. *Molecular Psychiatry, 16*, 729-737.

Chisholm, J. S. (1999). Attachment and time preference: Relations between early stress and sexual behavior in a sample of American university women. *Human Nature, 10*(1), 51-83. doi: 10.1007/s12110-999-1001-1

Costello, E.J., Sung, M., Worthman, C. & Angold, A. (2007). Pubertal maturation and the development of alcohol use and abuse. *Drug and Alcohol Dependence, 88S*, S50-S59.

Deardorff, J., Ekwaru, J. P., Kushi, L. H., Ellis, B. J., Greenspan, L. C., Mirabedi, A., . . . Hiatt, R. A. (2011). Father absence, body mass index, and pubertal timing in girls: Differential effects by family income and ethnicity. *Journal of Adolescent Health, 48*(5), 441-447. doi: 10.1016/j.jadohealth.2010.07.032

Del Giudice, M. (2009). Sex, attachment, and the development of reproductive strategies. *Behavioral and Brain Sciences, 32,* 1-21.

Ellis, B. J. (2004). Timing of pubertal maturation in girls: An integrated life history approach. *Psychological Bulletin, 130*(6), 920-958. doi: 10.1037/0033-2909.130.6.920

Ellis, B. J., & Essex, M. J. (2007). Family environments, adrenarche, and sexual maturation: A longitudinal test of a life history model. *Child Development, 78*(6), 1799-1817. doi: 10.1111/j.1467-8624.2007.01092.x

Ellis, B. J., Figueredo, A. J., Brumbach, B. H., & Schlomer, G. L. (2009). Fundamental dimensions of environmental risk: The impact of harsh versus unpredictable environments on the evolution and development of life history strategies. *Human Nature, 20*(2), 204-268. doi: 10.1007/s12110-009-9063-7

Ellis, B. J., & Garber, J. (2000). Psychosocial antecedents of variation in girls' pubertal timing: Maternal depression, stepfather presence, and marital and family stress. *Child Development, 71*(2), 485-501.

Kaplan, H. S., & Gangestad, S. W. (2005). Life history theory and evolutionary psychology. In *The handbook of evolutionary psychology* (pp. 68-95). Hoboken, NJ: John Wiley & Sons.

Kuzawa, C. W., McDade, T. W., Adair, L. S., & Lee, N. (2010). Rapid weight gain after birth predicts life history and reproductive strategy in Filipino males. *Proceedings of the National Academy of Sciences of the United States of America, 107*(39), 16800-16805. doi: 10.1073/pnas.1006008107

Moffitt, T. E., Caspi, A., Belsky, J., & Silva, P. A. (1992). Childhood experience and the onset of menarche: A test of a sociobiological model. *Child Development, 63*(1), 47-58. doi: 10.2307/1130900

National Institute of Child Health & Human Develoopment (NICHD) Early Child Care Research Network. (2001). Nonmaternal care and family factors in early development: An overview of the NICHD Study of Early Child Care. *Journal of Applied Developmental Psychology, 22*, 457-492. Doi:10.1016/S0193-3973(01)00092-2

Pesonen, A., Raikkonen, K., Heinonen, K., Kajantie, E., Forsen, T., & Eriksson, J.G. (2008). Reproductive traits following a parent-child separation trauma during childhood: A natural experiment during World War II. *American Journal of Human Biology, 20*, 345-351.

Rowe, D.C. (2000). Environmental and genetic influences on pubertal development: Evolutionary life history traits? In J. Rodgers, D. Rowe, & W. Miller (Eds.), *Genetic influences on human fertility and sexuality: Theoretical and empirical contributions from the biological and behavioral sciences* (pp. 148-168). Boston, MA: Kluwer.

Ryan, R. M. (2015). Nonresident fatherhood and adolescent sexual behavior: A comparison of siblings approach. *Developmental Psychology, 51*(2), 211.

Stearns, S. (1992). *The evolution of life histories*. Oxford, England: Oxford University Press.

Simpson, J. A., & Belsky, J. (2008). Attachment theory within a modern evolutionary framework. In *Handbook of attachment: Theory, research, and clinical applications* (2nd ed., pp. 131-157). New York: Guilford.

Simpson, J. A., & Belsky, J. (2016). Attachment theory within a modern evolutionary framework. In J. Cassidy & P. R. Shaver (Eds.), *Handbook of attachment: Theory, research, and clinical applications* (3rd ed.). New York: Guilford.

Simpson, J. A., Griskevicius, V., Kuo, S. I. C., Sung, S., & Collins, W. (2012). Evolution, stress, and sensitive periods: The influence of unpredictability in early versus late childhood on sex and risky behavior. *Developmental Psychology, 48*(3), 674-686. doi: 10.1037/a0027293

Skopp, N.A., & McDonald, R., Jouriles, E.N., & Rosenfield, D. (2007). Partner agression and children's externalizing problems: Maternal and partner warmth as protective factors. *Journal of Family Psychology, 21*, 459-467.

Stearns, S.C. (1992). *The evolution of life histories*. Oxford: Oxford University Press.

Surbey, M. K. (1990). Family composition, stress, and the timing of human menarche. *Socioendocrinology of primate reproduction* (pp. 11-32). New York: Wiley-Liss.

Tither, J. M., & Ellis, B. J. (2008). Impact of fathers on daughters' age at menarche: A genetically and environmentally controlled sibling study. *Developmental Psychology, 44*(5), 1409-1420. doi: dx.doi.org/10.1037/a0013065

van IJzendoorn, M. (1995a). Adult attachment representations, parental responsiveness, and infant attachment: A meta-analysis on the predictive validity of the Adult Attachment Interview. *Psychological Bulletin, 117,* 387-403.