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Konrad-Zuse-Strasse 1 · D-18057 Rostock · Germany · Tel +49 (0) 3 81 20 81 - 0 · Fax +49 (0) 3 81 20 81 - 202 · www.demogr.mpg.de

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Father absence and pubertal timing in Korean boys and girls

Susie Lee I lee@demogr.mpg.de
Hanna Semenchenko I semenchenko@demogr.mpg.de

This working paper has been approved for release by: Mikko Myrskylä (office-myrskyla@demogr.mpg.de),
Head of the Laboratory of Population Health, the Laboratory of Fertility and Well-Being, and the Research Group Labor Demography.

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Abstract

Background and objectives: Pubertal timing is a key life history trait with long-term health consequences in both sexes. Evolutionary theory has guided extensive research on developmental influences, in particular growing up without a father, on earlier menarche. Far less is known whether a similar relationship exists for boys, especially beyond western contexts. We used longitudinal data from the nationally representative sample of Korean adolescents, which provided us with a unique opportunity for studying male puberty using a hitherto underutilized biomarker: age at first nocturnal ejaculation.

Methodology: We pre-registered and tested a prediction that growing up in father-absent households is associated with earlier puberty in both sexes. Large sample size (>6,000) allowed testing the effect of father absence, which remains relatively uncommon in Korea, while adjusting for potential confounders.

Results: Average age at first nocturnal ejaculation was 13.8 years, falling within the range known from other societies. Unlike previous findings mostly for white girls, we did not find evidence that Korean girls in father-absent households had a younger age at menarche. Boys in father-absent households reported having their first nocturnal ejaculation three months earlier on average, and the difference was evident before age 14.

Conclusion and implications: The impact of father absence on pubertal timing is both sex- and age-dependent, and these differences may further interact with cultural norms regarding gender roles. Our study also highlights the utility of the recalled age of first ejaculation for male puberty research, which has lagged in both evolutionary biology and medicine.

Introduction

Puberty is a life history transition during which the dominant patterns of energy allocation switch from growth to reproduction [1]. While early reproductive maturation represents reproductive effort (e.g., earlier first birth [2,3] or greater reproductive success [4,5] in females), it is also associated with adverse health outcomes [6] such as risks of sex-steroid-sensitive cancers [7]. Consideration of such life history trade-offs has led research on developmental conditions that mediate adaptive variation in pubertal timing [8]. In industrialized societies, in which energetic stress is less acute, residing in a father-absent household is one developmental condition that has been shown to predict early menarche [9,10]. Based on the life history theory, it is argued that the earlier initiation of reproductive career is adaptation to the prospect of later adversity, if living without a father either serves as a signal indicative of a harsh environment later in life [11] or directly affects child's physical conditions that increase later morbidity or mortality [12].

Currently, however, much less is known whether father absence is related to pubertal timing in boys [13–17], reflecting a general lack of research on male life history [18]. This gap in our knowledge is unfortunate, at least for two reasons.

First, although the focus on girls has been explained by higher relevance of trade-offs between growth and reproduction in females [19], human males also face significant costs of reproduction. Humans are among the few mammalian species where paternal care has evolved, especially in the form of direct male care such as carrying young [20]. In humans, paternal care incurs energetic costs [21,22] involving physiological mechanisms that mediate trade-offs with mating effort [23,24]. It is thus expected that early puberty, to the extent that it reliably reflects reproductive effort, entails life history trade-offs in males as in females. Indeed, early puberty in boys is a risk factor for adverse health outcomes [6,25,26].

Second, sensitivity to early-life environment differs by sex [27,28]. Evidence suggests that males may be at greater risk of developing diseases as a result of stress experienced during pre-pubertal periods [29,30]. For example, in a study from Dominica, the stress physiology and testosterone level of boys were more sensitive to presence of father [31]. Moreover, sex differences in the response to father absence may further depend on cultural context, given the distinct developmental contexts created by cultural diversity in gender role and family relationship [32]. As yet, there is insufficient evidence to assess sex differences in the association between family environment and pubertal timing [14] especially beyond western societies [15].

To fill these gaps, the present study used panel data collected in South Korea (hereafter Korea) which provided us with a unique opportunity for studying male puberty using a hitherto underutilized biomarker: age at first nocturnal ejaculation. Male puberty has been understudied in part due to no commonly recognized milestone that is comparable to menarche [33]. The development of secondary sexual characteristics (e.g., pubic hair growth or voice break) is often used as a proxy for pubertal timing in boys. However, changes in these traits occur in stages over time [34], and as such, the exact timing of changes is difficult to pin down especially through self-reports. More importantly, development of secondary sexual characteristics is influenced by adrenarche, which is related to but is independent from gonadarche – growth and maturation of the gonads. Since gonardarche is responsible for menarche in girls and testicular enlargement in boys, biomarkers of gonadarche would reflect the pace of physiological process more directly related to the attainment of fecundity [35–37].

First ejaculation, as a discrete measure of an increase in testicular volume, has been identified as an important milestone in male puberty [38–40]. First ejaculation is closely correlated with bone age [39], and boys tend to provide a clear answer about its timing [40,41]. Whether self-reported or measured by the presence of sperm in urine, first ejaculation occurs during the stage 3 of sexual maturity rating [42], between 13-14 years of age across western and non-western populations [38,43–46]. Although nocturnal ejaculation occurs as an involuntary physiological reaction during sleep, the experience is conspicuous enough to be remembered especially if it is cultural recognized. In Korea, nocturnal ejaculation is frequently covered in surveys on adolescent health, and even features in TV series and movies.

Based on representative and large sample of Korean adolescents, the present study aimed to 1) describe the distribution of age at first nocturnal ejaculation and age at menarche in Korean adolescents; and 2) test the prediction that the onset of puberty was earlier for children living in father-absent households. Among studies that tested the prediction in a population of both sexes, findings have been so far mixed [47–51]. We thus started with the same prediction for both sexes. In many high-income Asian societies, like Korea, children growing up in father-absent households (usually due to divorce) remain uncommon in part due to high social and economic costs of divorce. We thus expected that, to the extent not living with their father placed significant psychosocial stress on Korean adolescents [52,53], it would accelerate pubertal timing in both sexes.

Methodology

We pre-registered the aim and the predictions of this study before conducting the analysis (https://osf.io/d2w9v/). We used R for all data processing and analyses [54].

Data

We used the Korean Children and Youth Panel Survey 2010 data, prospectively collected across seven waves (2010 to 2016) from 7,071 Korean adolescents born around 2000. The youngest, the middle, and the oldest cohorts were six, nine, and 12 years old, respectively, in 2010 when the survey began (Figure 1).

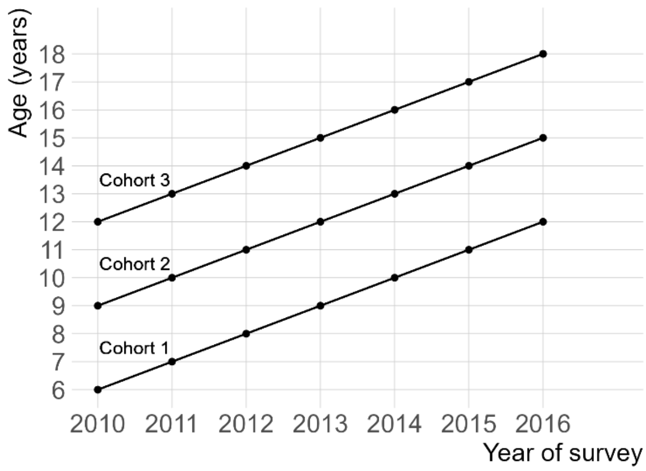


Figure 1. Three cohorts of the KCYPS 2010 data across seven waves. Initial sample sizes were cohort 1 (n = 2,342), 2 (n = 2,378), and 3 (n =2,351). For each of the three cohorts, the proportion of children retained at the end of the survey was 85.5%, 83.2%, and 80.0%, respectively.

Causal model

Based on a causal model postulating the pathway by which father absence affected pubertal timing in both sexes, we adjusted for household average income and cohort membership as covariates (for directed acyclic graph, see supplementary material 1). In the model, household income affected, and was affected by, father absence. Household income also influenced pubertal timing via various routes through which household income has been shown to affect child growth, development, and health in Korea [55–57]. Lastly, there were general differences across cohorts in household income, pubertal timing, and the chances of a child experiencing father absence. Thus, both household income and cohort were confounding factors in the pathways linking father absence with pubertal timing.

Variables

Age at pubertal onset

We used the child's self-reported age at first menstruation or nocturnal ejaculation as a proxy for the age at puberty. For children whose reported ages were inconsistent across different waves (29%), we took the earliest answer as the most reliable reminiscence of the event of interest. For children who reported not having started puberty in the latest survey wave, the observations were censored.

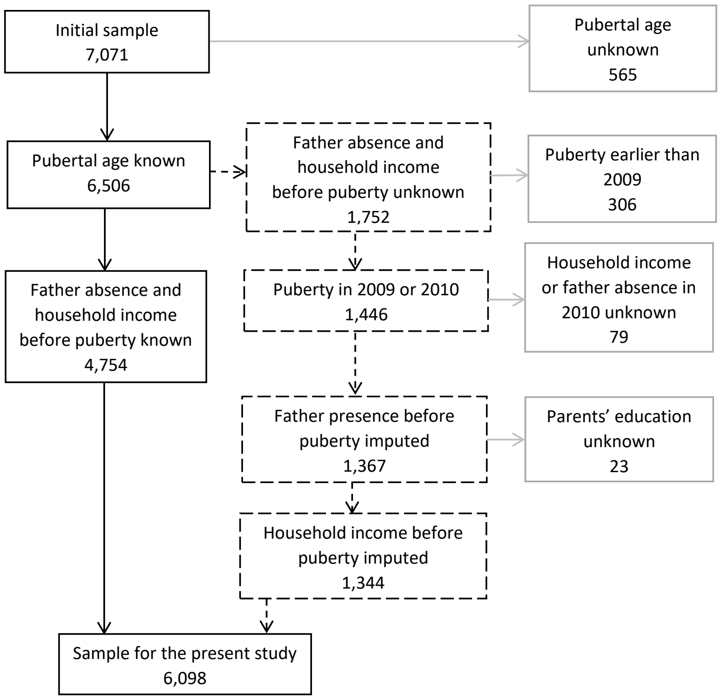


Figure 2. Flowchart showing how the analytic sample (*n* = 6,098) was selected from the initial sample (*n* = 7,071), and was prepared based on the availability of the necessary information. Excluded samples are indicated in gray-outlined boxes; and samples for which father absence and/or household income had to be imputed are indicated in dash-outlined boxes.

Father absence

We used information about the parental composition in a child's household that was collected in every wave as part of the guardian's survey. We took the following steps to process the longitudinal information on parental composition. First, we selected observations on father absence that were collected before or in the year of the reported age of puberty (or censoring), given that our focus was on the impact of father presence on the timing of puberty. Second, we reclassified nine parental composition values in the original data (supplementary material 2) into two states: a child was or was not living with his/her biological father in a given survey year. Third, these reclassified states formed a binary variable, which took values of one (with father) or zero (without father). This resulted in a time series of father absence status across years for each child. To make a variable that captured the "average" father absence status before a child entered puberty (or was censored), we operationalized father absence as "not residing with the biological father *most of the time* during the period preceding the onset of puberty." Lastly, reflecting this definition, a binary variable for father absence was created by assigning a value of one if the proportion of years of father absence in a child's time series of father absence status was greater than 0.5.

There were 1,752 children whose father absence information prior to pubertal onset was unknown (Figure 2) because their reported age of puberty was before or just in the year of the first survey wave. For the majority of these children (n = 1,367), we were able to impute their father absence status because children from younger cohorts were observed across the ages equivalent to the "pre-puberty" period of the children whose pre-puberty parental composition was unknown (supplementary materials 3.1). However, we were unable to impute the father absence status of 306 children whose pre-pubertal ages were not covered by the data (69 boys and 237 girls), and of 79 children for whom we lacked information for the imputation.

The causes of father absence could not be discerned from the data. We therefore referred to the 2018 Single Parent Survey (Ministry of Gender Equality and Family of Korea, 2019), which found that of the single-parent households in Korea, most were formed by divorce (77.7%), while smaller shares were formed by the death of a spouse (15.4%), being unmarried (4.0%), or separation (2.9%). Unfortunately, to the best of our knowledge, these causes of single parenthood have not been further broken down by household type or the age of the child. Therefore, we could only generally estimate that the father-absent households in our sample followed the abovementioned distribution.

Household income

Questions on annual household income were asked in every wave as part of the guardian's survey. Because household income was, on average, increasing over time, we used income levels rather than raw income values. Specifically, within each survey year, we assigned raw income values to a three-level ordinal scale – 1=low (below or equal to 50% of median annual income), 2=middle (above 50% and below or equal to 150% of median annual income), 3=high (above 150% of median annual income) – based on an annual income distribution indicator available from the Korean Statistical Information Service. For most children (73.7%), the household income level stayed the same across surveys. For cases in which the income level changed over time, we averaged the income levels of each child (e.g., 1-2-2 would be two). For the same reason as for father absence, we imputed the household income for the 1,344 children whose pre-puberty information on father absence could be successfully imputed, but whose household income information was missing (supplementary materials 3.2).

Statistical models

Data from a total of 3,237 boys and 2,861 girls entered the statistical analyses on the timing of pubertal onset. Using the R package “survival” [58] version 3.2-7, we estimated Cox proportional hazard models separately by sex.

Let $\lambda_0(\mathrm{t})$ be the baseline hazard of entering puberty for children, $\mathrm{X} = \{X^{\mathrm{F}}, X^{\mathrm{In}}, X^{\mathrm{C}}\}$ – vector of covariates such as father absence, income category, and panel, respectively. Then, $\lambda(\mathrm{t}|\mathrm{X})$ – the hazard of entering puberty given covariates X, assuming they influence baseline hazard proportionally, could be written as follows:

$$\lambda(\mathrm{t}|\mathrm{X}) = \lambda_0(\mathrm{t}) \cdot \exp(\beta\,\mathrm{X}),$$

where $\beta = \{\beta^{\mathrm{F}}, \beta^{\mathrm{In}}, \beta^{\mathrm{C}}\}$ is a vector of coefficients to be estimated: father absence, household income, and cohort membership, respectively. For different individuals i and j, relative hazard (hazard ratio)

$$\frac{\lambda(t|X_i)}{\lambda(t|X_j)} = \exp\left(\beta\left(X_i - X_j\right)\right)$$

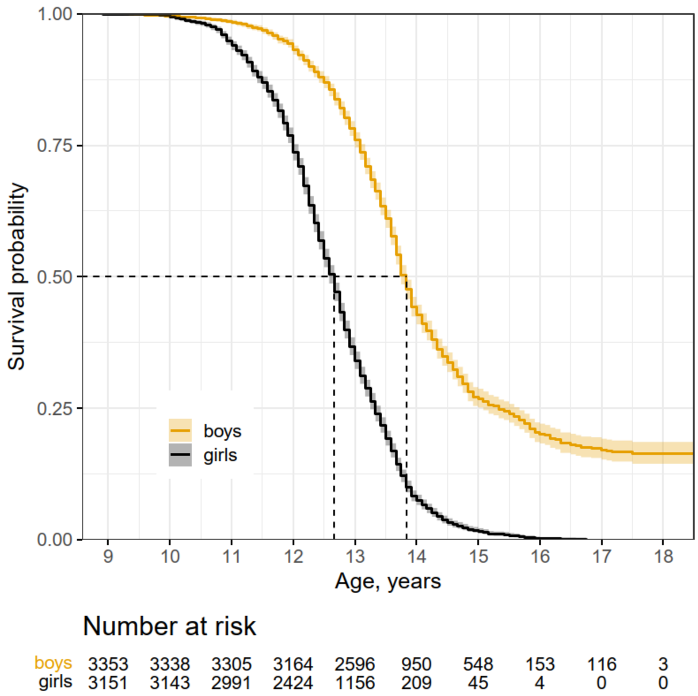
does not depend on time and on baseline hazard. After confirming that the relative hazard of father absence is not constant over time (i.e., the proportionality assumption is not met; Grambsch & Therneau, 1994), we estimated a time-varying coefficient model [60] in which the effect of father absence can change across age. We specified a father absence covariate of the simplest linear type:

$$\beta^F(t) = \beta_0^F + \beta_1^F \cdot t$$

Results

1) Age at menarche or at first nocturnal ejaculation in Korean adolescents

Age at menarche or at first nocturnal ejaculation was, on average, earlier in girls (12.7 years) than in boys (13.8 years; Figure 3). Likewise, both the earliest and latest reported ages at pubertal onset were earlier in girls 8.9 and 16.8, respectively (9.1 and 17.5 for boys, respectively). The earliest reported age at pubertal onset was 9.1 for boys and 8.9 for girls, and the latest reported age at pubertal onset was 17.5 for boys and 16.8 for girls. While all girls reported experiencing their first menstruation by around age 16, about 16% of boys reported that they had not yet experienced their first nocturnal ejaculation by that age.



		n	events	rmean*	se(rmean)	median	0.95LCL	0.95UCL
All panels	boys	3353	2148	173 (14.4)**	0.530	166 (13.8)**	165	166
	girls	3152	3021	152 (12.7)	0.221	152 (12.7)	151	152

* restricted mean with upper limit of 222 months.
** values in years.

Figure 3. Kaplan-Meier estimates of the survival curves for pubertal age – menarche for girls and first nocturnal ejaculation for boys – in Korean adolescents.

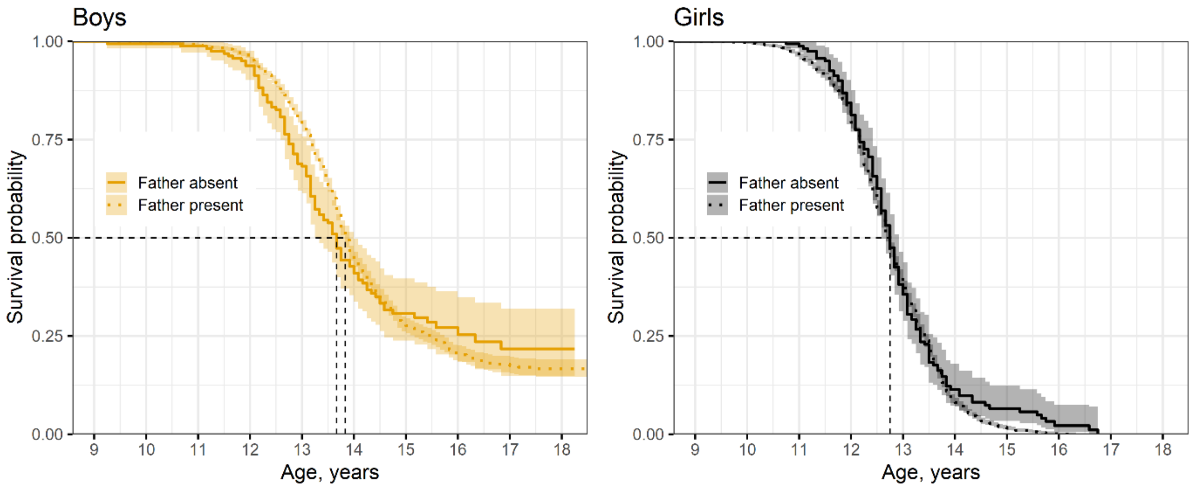
Note: Calculation based on the KCYPS 2010 sample with known information about the age at puberty including censored age (*n* = 6,505).

2) Impact of father absence on the timing of menarche or first nocturnal ejaculation

In our sample, 5.23% of boys and 5.92% of girls spent the majority of their time prior to the onset of puberty not living with their biological father. Father-absent households were predominantly high-income (73.58%) and rarely low-income (0.69%), whereas father-present households were mostly middle-income (64.17%) and similarly distributed between low- and high-income strata.

The survival curves of pubertal timing (Figure 4, upper panel) show that there were differences between boys depending on whether they were or were not living with their father (log rank test for difference: χ^2 = 5 on 1 degrees of freedom, p = 0.03), but not between girls (χ^2 = 0.3 on 1 degrees of freedom, p = 0.6). The average age at first nocturnal ejaculation was 13 years and two months for boys who were not living with their father, or approximately three months younger than that for boys who were with living with their father.

The survival curves also suggested that the impact of father absence on pubertal timing differed by age (Figure 4, upper panel). The Cox models with father absence as a covariate with a time-varying coefficient shed further light on the sex differences in the age-dependency of the impact of father absence (Figure 4 lower panel; supplementary materials 4.1). The risk of experiencing nocturnal ejaculation was higher among boys who were not living with their father than among boys who were; however, the effect was evident before age 14, starting from the relative risk of four (95% confidence interval [CI] = 2 to 9) at age nine, and tapering off toward age 14, when the relative risk hit one. At higher ages, it was difficult to ascertain the effect due to a lack of statistical power for the small relative risk closer to one (see Table S2 for model outputs). By contrast, the relative risk of pubertal onset among girls living in father-absent households ranged around one at all ages. These findings corroborate the abovementioned observation that there was little evidence that among girls, pubertal timing differed by father absence status. The findings remained unchanged when we estimated the effect of father absence stratified by cohort, or when we excluded the sample for which father absence status had to be imputed (supplementary materials 4.2, 4.3.)



Number at risk

	9	10	11	12	13	14	15	16	17	18
Boys: Father absent	161	160	159	151	110	50	32	15	10	1
Boys: Father present	3076	3070	3050	2968	2459	898	515	138	106	2
Girls: Father absent	160	160	159	135	60	14	8	2	0	0
Girls: Father present	2699	2695	2615	2236	1080	193	37	2	0	0

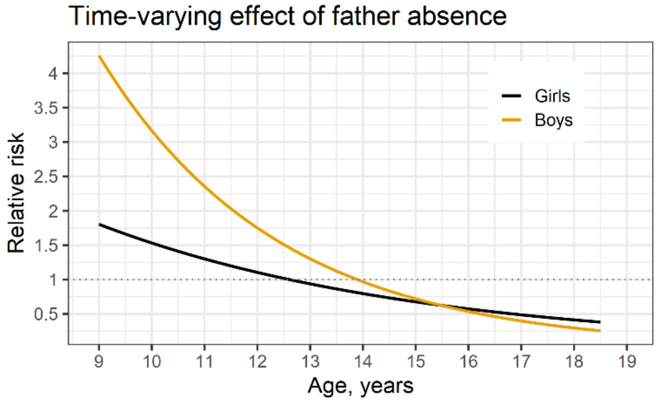


Figure 4. Upper panel: Kaplan-Meier estimates of survival curves for the age at puberty for Korean boys and girls living in father-absent households (solid lines) and in father-present households (dotted lines). Lower pane: Relative risk of pubertal onset for children living without their father compared to that for children living with their father. Calculations of the relative risk are based on the Cox models with father absence as time-varying coefficient (see supplementary materials 4.1 for full model outputs.)

Note: Calculation based on the KCYPS 2010 sample with known information about the age at puberty, including censored age, whether a child was or was not spending the majority of his/her pre-pubertal period in a father-absent household, and household income (n = 6,098).

Discussion

Our results for Korean adolescents suggest that pubertal onset was earlier among boys who were not residing with their father. Early first nocturnal ejaculation was associated with the early initiation of sexual intercourse in Korea [46], and was a stronger predictor of sexual behavior than other secondary sexual characteristics in Zimbabwe [43]. Thus, to the extent that early first nocturnal ejaculation predicts the earlier initiation of reproductive effort, our findings for Korean boys provide evidence of faster reproductive maturation among children growing up without their father [11,61]. A crucial next step will be to test the pathways through which early pubertal onset represents an adaptive response in these boys. For example, early puberty in boys predicts taller height [48,62], which in turn has been shown to confer greater reproductive success in multiple populations [63,64].

One possible proximate mechanism by which father absence was related to earlier puberty in Korean boys is the activation of the hypothalamic-pituitary-adrenal (HPA) axis, which in turn interacts with the hypothalamic-pituitary-gonadal (HPG) axis [65]. Another possible mechanism is genetic confounding [66] since pubertal timing has a strong genetic basis in both sexes [67]. Recent works on girls have so far suggested that father absence and genetic risk of early menarche are independent and additive predictor of early menarche [68]. The relative high-income of the father-absent households suggests that the impact of father absence was likely mediated as psychological rather than energetic stress. Due to a lack of physiological data, we cannot determine whether the Korean boys who were living in father-absent households indeed experienced a heightened stress response prior to pubertal onset [31]. A study based on the same KCYPS sample [53] reported high overall levels of self-reported stress among children living in single-parent households, with no differences by sex. However, these findings may not reflect the actual stress response, especially given the cultural norms in Korea discouraging the acknowledgement of emotional hardship.

We found little evidence of earlier menarche among Korean girls growing up in father-absent households. A recent review has also found that the direction of the relationship between father absence and pubertal timing is more variable among girls in non-WEIRD (western, educated, industrialized, rich and democratic) societies than among girls in WEIRD societies [15]. Although this observation may be attributable to the smaller number of studies for non-WEIRD societies, it could also suggest that sex differences in early-life effects [27] interact with different social norms about gender roles and their development. For example, earlier reproductive maturation only among boys from father-absent households may reflect the patriarchal norms that centralize male authority running through the father-son axis in Korean families [69]. In this cultural context, the absence of the father is likely to have a direct impact on boys, since boys tend to identify with their father [70], especially as a patriarch within the household. This implies that growing up in a father-absent household may prompt a boy to take on the “father” role at an earlier age. Thus, it is important to study the impact of father absence on pubertal timing within a cultural context in which there might be sex differences in the observed patterns [15].

Our findings highlight the utility of the age at first nocturnal ejaculation as a convenient biomarker in the study of male puberty [39,40,43,71]. In higher primates, including in humans, the onset of puberty is initiated when the pulsatile secretion of hypothalamic gonadotropin-releasing hormone (GnRH) resumes after developmental quiescence, and triggers the activation of the pituitary-gonadal axis [35,36]. In the pubertal transition, GnRH pulses increase particularly at night [72], which may explain why the first spontaneous ejaculation occurs while sleeping. The average age at first nocturnal ejaculation among the boys in our sample was within the range (13-14 years) reported for other societies [40]. It is worth noting that previous studies mostly reported the age at first ejaculation, and not necessarily the age at first *nocturnal* ejaculation, which is broadly understood as an involuntary reaction. Thus, the overlapping age range suggests that the first ejaculation – regardless of how it is achieved – occurs during a specific age window in boys. Moreover, in line with other sex differences in the pubertal transition, the first nocturnal ejaculation was about one year later than the first menarche. For this reason, among children who were followed to age 16.75, all girls reported having experienced their first menstruation by that age, whereas 12.28% boys reported that they had not yet experienced their first nocturnal ejaculation by that age. This observation might also suggest that the first nocturnal ejaculation, unlike menarche, is a milestone that not all boys achieve or recall, or both. More studies across societies with different levels of cultural "visibility" of nocturnal ejaculation could help to clarify these points.

We provide additional evidence that among boys, the impact of father absence is age-dependent. In our study, the impact was restricted to the pubertal transition that occurred during the younger age window of below 14 years. Given that our data on parental composition spanned ages six and older, our findings may support the general claim that mid-childhood (juvenility that precedes puberty) is a sensitive period for calibrating sex differences in reproductive strategies [73]. However, without further information from the early childhood or at birth [47], we cannot pinpoint the exact time window when father absence affects pubertal timing. Father absence is associated with different family circumstances, ranging from parental divorce, to the death of the father, to temporary separation due to a parent's job, to co-residence with other family members – each of which is likely to have different effects on a child's growth and development. The lack of detailed family information beyond the absence of the father, as well as the very low proportion of father-absent households in Korea, limited our capacity to interpret the broader implications of our findings.

Conclusion

The pace of reproductive maturation is a key life history trait with crucial implications for population health, even more so given the global trends of earlier puberty. To help better understand developmental influences on pubertal timing, we fill current gaps in the understanding of male puberty and impact of father absence in non-western societies. We found that Korean boys, but not Korean girls, who did not reside with their father tended to have earlier pubertal timing. Our findings emphasize the need to consider both sexes and across cultures to better understand the effects of early-life conditions, such as father absence, on reproductive maturation.

Acknowledgements

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Data & Codes

The original data are available from the National Youth Policy Institute website (https://www.nypi.re.kr/archive/mps/program/examinDataCode/dataDwloadAgreeView?menuId=MENU00226). The R codes used to conduct statistical analyses will be saved at the project website upon publication (https://osf.io/d2w9v/).

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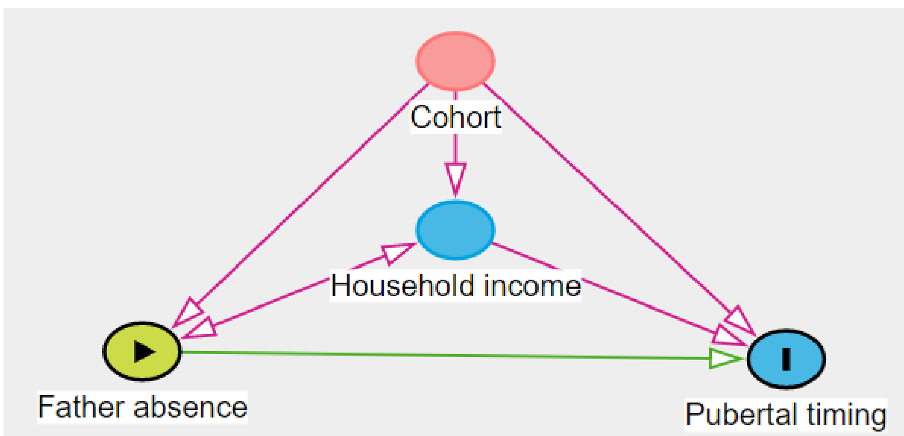
Contents

Supplementary material 1. Directed acyclic graph of the relationship between father absence and pubertal timing.

Confounding paths are indicated in red.



Supplementary material 2. Parental composition types as collected in the original data.

Nine types of information on the parental composition of child’s household were collected. The values 1, 2, 4 indicate the information we coded as ‘father present’ status.

Value for the parental composition variable	Meaning
1	both biological parents are present
2	only biological father
3	only biological mother
4	biological father and stepmother
5	biological mother and stepfather
6	stepfather and stepmother
7	only stepfather
8	only stepmother
9	any parents are absent

Imputing father absence status

Our aim was to obtain a generalized linear model (GLM), that predicts whether or not a child spent majority of time without biological father during three years preceding the first survey wave, given the father absence status at the first survey wave and other information potentially predictive of parental composition of a household – sex of a child, region of residence, and household income. We selected 4,009 children from the younger cohorts who were observed during the ages equivalent to three years preceding and inclusive of the 1st grade middle school. We randomly divided the data into training and test data sets, and tested several specifications of GLMs using the training data. We selected the one that performed best in terms of predicting the test data set as well as model comparison. The obtained model was used to impute the father absence status prior to pubertal onset.

Imputing household income

To impute household income for at least the three years preceding the beginning of the survey (2007, 2008, 2009), we first constructed a model for log-transformed household income using all the available data on household income from the KCYPS. To reflect the data structure of repeated income observations within individual households, we estimated a mixed-effects model (aka multi-level model), in which fixed-effects were membership to three cohorts, year of survey, mother's highest education, father's highest education, and random-effects were individual ID and region to capture heterogeneity across households and regions. We specified a model as:

$$y_i = \alpha_{j[i]} + \alpha_{k[i]} + X_i\beta + \epsilon_i$$

$$\alpha_j \sim N(\mu_\alpha, \sigma_\alpha^2), \text{for } j = 1, \ldots, J$$

$$\alpha_k \sim N(\mu_\alpha, \sigma_\alpha^2), \text{for } k = 1, \ldots, K$$

where we have observations of income y_i of $i = 1, \ldots, n$ clustered within individuals $j = 1, \ldots, J$, and within regions k = 1, …, K. α_j and α_k are individual intercepts (random-effects) assumed to follow normal distribution. $X_i\beta$ is a matrix of fixed-effects specific to income (membership to three cohorts, year of survey, mother's highest education, father's highest education). According to model comparison, interaction between cohort membership and year of survey improved the model fit. This suggests that, household income not only increased over time, but the degree of increase differed between cohorts. We then used the obtained model, to impute household income for the children whose father absence (*n* = 1,367) we could successfully impute in the abovementioned procedure. Some of them (*n* = 23) had no information on parents' education during the period of interest, and thus could not be imputed for their household income (see Figure 2 in the main text).

Survival analyses on pubertal timing

Analyses without imputed information on father absence