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Growing up under generalized violence: An ecological study of homicide rates and secular trends in age at menarche in Colombia, 1940s–1980s

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ABSTRACT

We examined secular changes in mean age at menarche among 5577 Colombian women born between 1941 and 1989, and correlated those changes with nation-wide rates of homicide and real gross domestic product per capita (GDP) at the year of birth and at the year at age 5, within predefined historical periods. The mean (standard error) rate of change in age at menarche by year of birth was −0.55 (0.02) years/decade. The rate of change was not constant, but varied between historical periods as follows: −1.44, −0.14, −0.60, and −0.36 years/decade for the periods 1941–1947, 1948–1958, 1959–1978, and 1979–1989, respectively. The changes in age at menarche correlated positively with the changes in the nation-wide rates of homicide within such periods; i.e. decelerations in the menarcheal trend coincided with increases in the rates of homicide and vice versa. The correlation was higher with the rates of homicide when women were 5 years of age ($r = 0.99$, $p = 0.01$) compared to the rates of homicide at the year of birth (0.55, $p = 0.45$). There were negative correlations between the changes in age at menarche and the changes in GDP, but they were weaker than those with the rates of homicide. These results could suggest a potential impact on maturation of psychosocial stress in childhood due to exposure to a generalized atmosphere of violence and fear.

1. Introduction

Menarche is a key event in the reproductive life of women and constitutes a useful indicator of the rate of maturation that is relatively easy to obtain in population studies. Mean age at menarche experienced declines in Europe and the United States from the 19th to the 20th century that varied in magnitude from about 0.2 to 0.4 years/decade (Tanner, 1968; Wyshak and Frisch, 1982; de Muinich Keizer and Mul, 2001; Euling et al., 2008), and in Japan during the first half of the 20th century (Hoel et al., 1983). These changes have been generally attributed to improved living standards (Komlos, 1989; Cole, 2000). In countries with atypical patterns of development, the secular trend in menarche is variable and still strongly influenced by inequalities in socioeconomic status, access to adequate nutrition, and availability of health and sanitation services. In Latin America, secular changes towards early menarche during the second half of the 20th century have been documented in Brazil (Kac et al., 2000), Venezuela (Farid-Coupal et al., 1981), and Mexico (Malina et al., 2004).

Many studies have examined the correlates of secular changes in menarche from a historical perspective. Among Norwegian women, Liestøl found a close, negative relation between changes in the average age at menarche and the gross domestic product (GDP) at the women's year of birth (Liestøl, 1982); this association suggested an influence of

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living standards around the time of birth on the tempo of biological maturation. Other authors documented menarcheal delays in relation to exposure to war conditions: during the Second World War (van Noord and Kaaks, 1991) and, more recently, during the conflict in the Balkans region (Tahirovic, 1998; Prebeg and Bralic, 2000). The effect of recent historical events on biological maturation indicators in Latin America has been understudied. The examination of this question becomes particularly relevant in countries such as Colombia, which has suffered major political and social unrest during most of the 20th century, with substantial impact on living standards. Violence is the most salient consequence of such unrest, and is currently considered to be the primary public health problem in the country and the major contributor to reductions in quality of life (Franco, 2003b). The rates of homicide are recognized as the most reliable indicator of the magnitude of violence in Colombia and, by 2001, were the highest of any country in the world (Franco, 2003b). It is unknown to what extent such conditions could be related to physical growth and maturation. We hypothesize that high levels of nation-wide violence are associated with delays in age at menarche.

This manuscript examines secular trends in age at menarche between the 1940s and the 1980s in a group of Colombian women, to explore the relations between those trends and indicators of violence (national rates of homicide) and economic development (real GDP per capita), and to contrast Colombia's secular trend in menarche with trends reported in other Latin American countries.

2. Subjects and methods

2.1. Data sources

Between January 1998 and January 2001, we conducted a study of the determinants of age at menarche among all female students entering an undergraduate program in the National University of Colombia (Bogotá). Of the 4485 newly registered female students in this period, 3247 (72.4%) agreed to participate and completed a questionnaire during their orientation week while 1238 did not attend the sessions when the questionnaire was administered or declined participation.

In the questionnaire, the participants were asked to recall the date and age in years of their first menstruation. In addition, the students were asked to report their mother's and sisters' date of birth and age at menarche if they knew it. The self-administered questionnaire also included questions regarding the student's date and place of birth, place of residence at menarche, educational level and occupation of their parents, the number and kinship of family members she was living with at the time of menarche, and practice of physical activity before and at the time of menarche. Parental occupation of the head of the household was used to define socioeconomic status according to the classification validated by Victora et al. (1992) in a comparable setting. The adaptation of this classification system to our study population appears in (Chavarro et al., 2004).

Of the 3247 participating students, 3206 (98.7%) reported the date or age at menarche. We defined age at menarche in decimal years by calculating the difference between the reported date of menarche and the date of birth in days divided by 365. For women lacking precise dates of menarche, either the 15th day of the month (for those who provided the year and month but not the day) or the 15th day of the 6th month (for those who only provided the year) were imputed for the calculation. Among participants who did not report dates but only ages we added 0.5 years to their age at menarche to account for rounding down of the reported age (Livson and Mc, 1962; Casey et al., 1991).

Crude rates of homicide from 1941 to 1991 were obtained from the National Department of Statistics (DANE), as compiled by Cárdenas (1994). From 1992 onwards, we used figures published by the National Police, as compiled by Franco (2003a). Real GDP per capita from 1950 to 2000 was obtained from the Penn World Table database (Heston et al., 2002).

2.2. Data analyses

We conducted analyses among all women for whom age at menarche was known ($n = 5577$). These women were born between 1941 and 1989. Of them, 3206 were interviewed students who provided information on their age at menarche; 948 were students' mothers, and 1423 were students' sisters. Students who provided information on their mothers' age at menarche did not differ significantly from those who did not provide this information in their socioeconomic status, size of birthplace, or maternal education level. However, they were significantly younger at the time of the study than their non-reporting pairs; which may reflect a generational effect by which discussion of sexual development information between mothers and daughters has become more common in recent years, independent of education or social class.

We considered four conventionally predefined historical periods that have coincided with major changes in the rates of homicide in the country during the later 20th century. The first period ranged from 1941 to 1947. These years correspond to the later years of the "*Liberal Republic*" (Bushnell, 1996), which started in 1930 with the transition from an almost half-century of Conservative-party hegemony to a Liberal-party regime that was to last until 1946. The recorded homicide rates between 1938 and 1947 were the lowest for the rest of the century. The second period included the years from 1948 to 1958. This decade is generally known as the age of "*Violence*", coinciding with an increase in homicide rates related to an irregular war between liberals and conservatives that worsened after the killing of the liberal leader Jorge Eliécer Gaitán in 1948 (Guzmán Campos et al., 1962). The third period comprises the years from 1959 and 1978 (Bushnell, 1996) and corresponds to the 16 years of "*National Front*", an agreement between the two traditional parties (Liberal and Conservative) to take turns in government as a means to control the violence, plus the first post-National Front presidential period during which bi-partisan sharing of

public posts appointed by the Executive was still required. This period coincided with a substantial decline in the rates of homicide. The final period ranged from 1979 to 1991 and included the greatest peak of homicide rates recorded during the century. This peak coincides with an increasingly complex political-military conflict that involves an armed confrontation between extreme left-wing guerrilla groups and the government, the mass killings of civilians (''massacres'') by extreme right-wing paramilitary organizations often supported by parts of the government's military, illegal drug trafficking, and social and political intolerance (Franco, 2003b). In addition to the political context of this violence, others have been offered: an economic context represented by the structural inequality of Colombian society; a cultural context represented by the underestimation of the value of life, unequal access to education, and psychological components; and a legal context, represented by the inefficiency of the country's judicial system (Franco, 2003a).

To estimate the secular trend of the age at menarche, first we fitted a linear regression model with age at menarche as the outcome and year of birth as the predictor. Then we smoothed the trend using restricted cubic splines (Durrleman and Simon, 1989) for year of birth, to examine whether the secular trend was constant during the study period. Given that it was not constant, we estimated the secular trend in menarche (rates of change) separately for each of the four historical periods defined above by introducing into the linear regression model indicator variables for each period and interaction terms between these variables and year of birth. Given the potential of confounding for shared familial factors, the estimation of period-specific secular trends in menarche was adjusted for within-family correlations (mother-daughters and between-sisters) through the specification of an exchangeable correlation structure in the regression model (Fitzmaurice et al., 2004) (PROC GENMOD, SAS Institute Inc, Cary, NC). Next, we estimated the change in the rates of homicide during the same periods, with the use of linear regression, assuming a constant change within periods. Finally, we calculated the correlation coefficients (Pearson) between the periods' changes in age at menarche and the changes in the rates of homicide.

We repeated the comparison between the secular changes in menarche and rates of homicide after introducing a lag time of 5 years, in order to examine whether the potential influences of homicide on age at menarche were stronger during childhood (at age 5) than around the time of birth. For this comparison, we included an additional period from 1992 to the latest year when women were 5 years of age. We followed a similar approach as that described above, to examine the correlations between the changes in age at menarche with the changes in GDP per capita.

Data management and analyses were carried out using the Statistical Analyses System software, version 9 (SAS Institute Inc, Cary, NC).

2.3. Ethical considerations

The study protocol was approved by a scientific committee of the Students' Health Division of the National University of Colombia. All the study procedures were conducted following the guidelines of the Declaration of Helsinki (World Medical Association, 2001) and the regulations for human subjects research of the Colombian Ministry of Health.

3. Results

The proportions of women by year of birth within the historical periods 1941–1947, 1948–1958, 1959–1978, and 1979–1989 were 2%, 11%, 22%, and 65%, respectively (Table 1).

Socio-demographic characteristics are available for the group of female students who filled out the questionnaire, and were reported previously (Chavarro et al., 2004). In brief, the majority of students (74%) were born in large cities (population >1,000,000), and 72% in Bogotá; 63% had mothers who had completed secondary education. The students' families socioeconomic status distribution was as follows: 27% upper-middle, 19% middle, 34% lower-middle, and 20% working class. We do not assume the same socioeconomic classification for the mothers or sisters around their age at menarche due to their potential inter- and intra-generational social mobility. The correlation between the students' and their mothers' age at menarche was 0.21 and between the students' and their sisters' ranged from 0.09 to 0.31.

Pooling the data from the students, sisters, and mothers, the overall average (SE) estimate for the secular trend in age at menarche between 1941 and 1989 was

Table 1
Number of Colombian women with data on age at menarche during each historical period.

Period	Year of birth				Year at age 5			
	Mothers	Sisters	Students	Total	Mothers	Sisters	Students	Total
1941–1947	128			128	21			21[a]
1948–1958	577	12	1	590	365	2		367
1959–1978	243	543	458	1244	562	200	72	834
1979–1991		868	2747	3615[b]		1171	3134	4305
1992–1994						50		50
Age at interview[c]	44.5 (5.5)	19.7 (5.8)	18.5 (2.5)					
Age at menarche[c]	14.3 (1.9)	13.1 (1.3)	12.7 (1.3)					

[a] These women were further excluded from the analyses of year at age 5 since they only contributed information to the last two years of the period.
[b] The last year of birth during this period was 1989.
[c] Mean (SD).

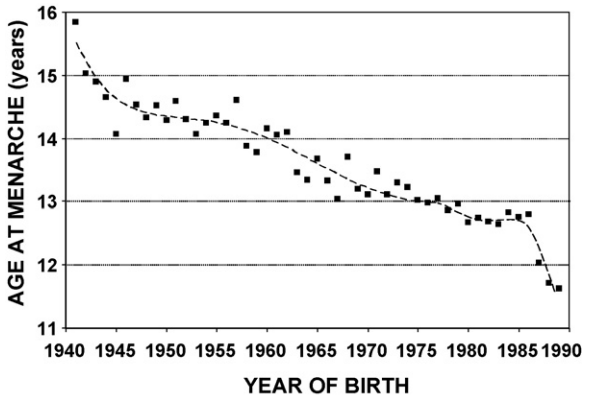

Fig. 1. Mean age at menarche in a group of Colombian women by year of birth.

−0.55 (0.02) years per decade. However, this change was not constant over time as evidenced by regressing the mean ages at menarche on the year of birth with the use of restricted cubic splines (Fig. 1).

An initial period of rapid decline was followed by a plateau; then there was another period of decline, a second deceleration, and a final rapid decrease. These changing secular trends in age at menarche could be characterized within the historical periods that we considered, both for the year of birth and for the year at age 5. For year of birth, for example, the rates of change in age at menarche were −1.44, −0.14, −0.60, and −0.36 years/decade for the periods 1941–1947, 1948–1958, 1959–1978, and 1979–1989, respectively (Table 2). We also estimated the corresponding rates of change for the rates of homicide and GDP within the same periods (Table 2).

Next we correlated the changes in age at menarche with the changes in the rates of homicide and the GDP of each period, considering age at menarche both by year of birth and year at age 5 (Table 3). There were strong positive correlations between the trends in homicide and the trends in menarche within each period, both for menarche by year of birth and menarche by year at age 5. The correlation coefficient was highest for menarche by year at age 5 ($r = 0.99$, $p = 0.01$). This means that women who were five years of age during periods with an increasing trend in homicide experienced a deceleration of their secular change in age at menarche, whereas those who were five years old during periods of low or decreasing trends in homicide had more pronounced trends towards early menarche. The very high correlation at age 5 would suggest that these changes were not only reciprocal but proportional to each other between periods (Fig. 2).

Table 3
Correlations between change in age at menarche and change in the rate of homicide and real GDP in Colombia during historical periods of the late 20th century.

Age at menarche	Homicide rate	GDP per capita
By year of birth	0.55, $p = 0.45$	−0.30, $p = 0.80$
By year at age 5	0.99, $p = 0.01$	−0.29, $p = 0.71$

We also found the expected negative correlation between the rates of change in age at menarche and the rates of change in GDP, meaning that the increases in GDP were accompanied by decreases in the average age at menarche (Fig. 3), as reported previously by Liestøl (1982) in Norway.

Remarkably, the correlations of changes in age at menarche with changes in GDP were lower than those with changes in the rate of homicide. In supplemental analyses, we estimated the partial correlation coefficient between the changes in age at menarche and homicide rates adjusting for GDP, given that GDP was correlated with the yearly rate of homicide ($r = 0.77$) and thus could be a confounder of the relation between menarche and homicide. The association remained unchanged after adjustment for GDP (partial $r = 0.99$, $p = 0.10$).

Finally, we compared the secular trend in age at menarche between our sample and two other Latin American urban settings for which published data were available in at least three decades of the 20th century: Brazil (Kac et al., 2000) and Venezuela (Farid-Coupal et al., 1981) (Fig. 4). The data from these countries, albeit from single locations (Rio de Janeiro in Brazil and Carabobo State in Venezuela), were part of nation-wide studies and can be presumed to have included all socioeconomic strata in a representative manner. The average rates of change in age at menarche over time were different in the three countries: −0.1, −0.6, and −0.55 years/decade in Brazil, Venezuela, and Colombia, respectively. By the first decade when data were available in our sample, the mean ages at menarche in Venezuela (13.6) and Brazil (12.8) were already lower than the average for Colombia (14.5). Thereafter, the trend in Venezuela decreased rapidly (about 1 year/decade) to 12.6, the mean age around which

Table 2
Mean (SE) secular change per decade in age at menarche (years), homicide (rate/100,000), and GDP (USD) in Colombia during historical periods of the late 20th century.

Period	By year of birth			By year at age 5		
	Menarche	Homicide	GDP	Menarche	Homicide	GDP
1941–1947	−1.44 (0.92)	1.1 (7.6)				
1948–1958	−0.14 (0.26)	23.0 (3.9)	180 (150)	−0.55 (0.35)	23.0 (4.5)	180 (146)
1959–1978	−0.60 (0.07)	−9.4 (1.6)	698 (45)	−0.63 (0.10)	−9.4 (1.8)	698 (44)
1979–1991	−0.36 (0.11)[a]	42.8 (3.9)	1737 (111)	−0.41 (0.08)	51.6 (3.5)	1850 (84)
1992–1994				−0.81 (1.75)	−40.0 (33.2)	2313 (802)

[a] The last year of birth during this period was 1989.

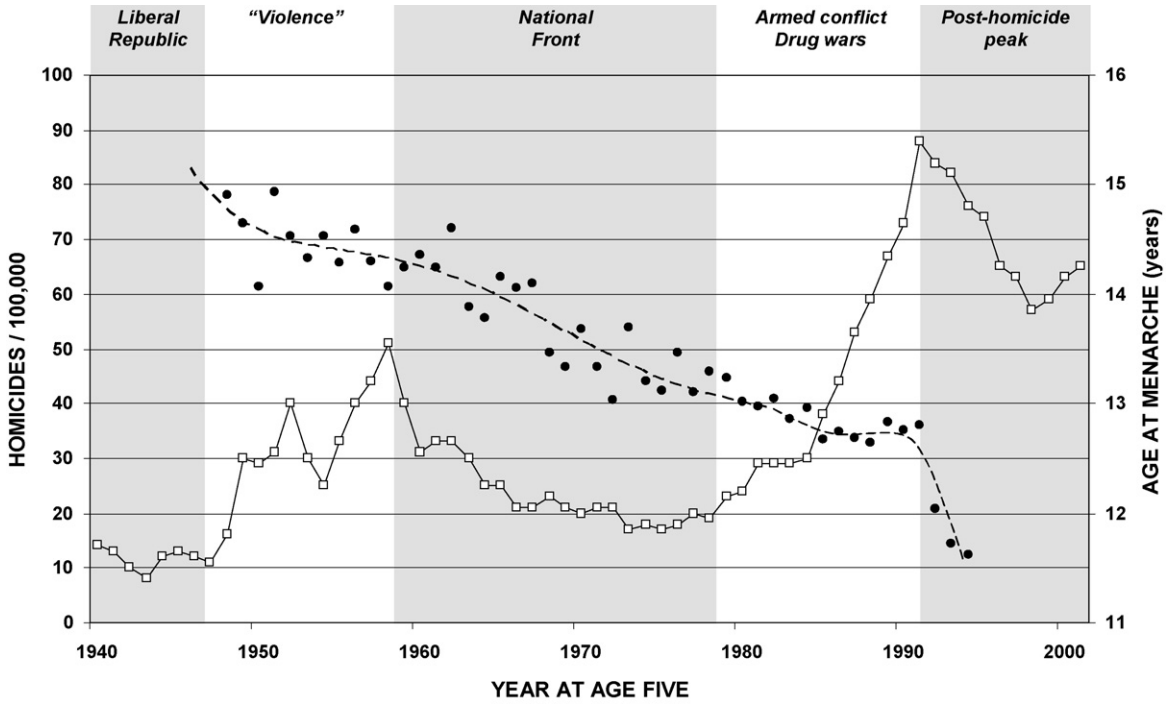

Fig. 2. Mean age at menarche by year at age 5 and crude homicide rates in Colombia.

menarche appeared to stabilize. The trend in Brazil was the slowest and appeared to be constant. Compared to the trend from Venezuela, the secular trend in Colombia appeared to be delayed for a decade and seemed to have extended over at least two additional decades; as a result, the average age at menarche of 12.6 years reported in Venezuela for the 1950s was reached in Colombia only by the 1980s.

4. Discussion

We found a secular trend towards earlier menarche during the second half of the 20th century in a group of Colombian women. The trend was not constant; periods of deceleration coincided with increasing national rates of homicide. The correlation of the rates of change in age at menarche with the rates of change in homicide rates was larger than that with change in real GDP. Also, the correlation with age at menarche was stronger when homicide rates were considered by year at age 5, compared to homicide rates by the year of birth.

The mechanisms to explain an association between exposure to high nation-wide rates of homicide around birth and during childhood and age at menarche are unclear. Assuming that high homicide rates reflect an environment of violence, the present results may suggest an important, novel association between an indicator of the "material and moral condition of society" (Tanner, 1986) and a key developmental event. Our study, however, cannot answer whether delayed menarche is related to a violent environment per se or rather to the perception of a violent environment. Early

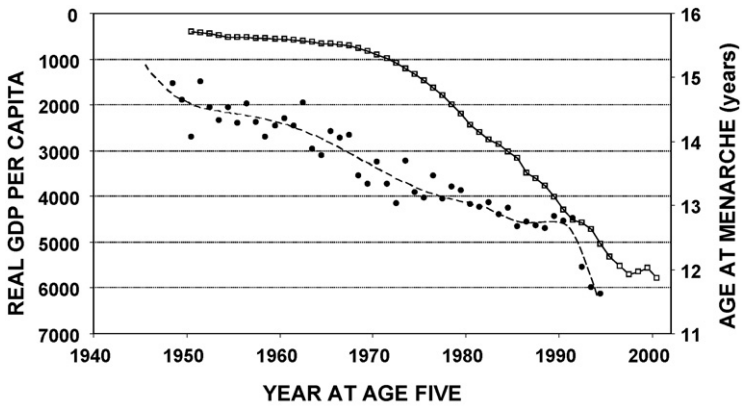

Fig. 3. Mean age at menarche by year at age 5 and real GDP per capita in Colombia. The *y* axis for real GDP per capita has been reversed.

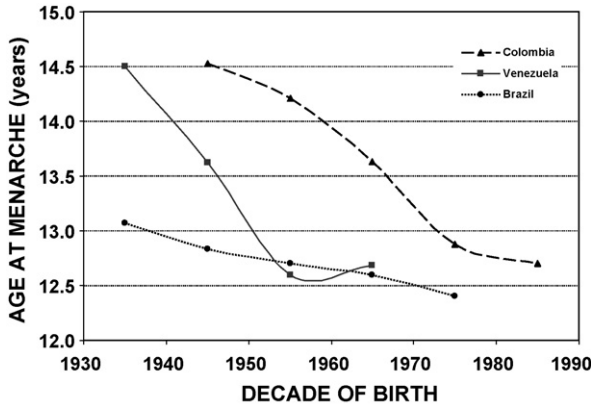

Fig. 4. Mean age at menarche by decade of birth in Colombia, Venezuela, and Brazil.

laboratory experiments in animals showed that lack of control over a painful, stressful stimulus, rather than the stimulus per se was related to stomach ulcers and death (Brady, 1958). By analogy, living in an environment of violence may contribute to chronic anxiety over violence, which may be a factor associated with age at menarche, even if the girls were not individually affected by violent events. Previous studies have shown that age at menarche could increase during wartime, when there is a substantial burden of psychosocial stress to the population. During the Second World War, for example, there was an increase in mean menarcheal age in the Netherlands (van Noord and Kaaks, 1991), Belgium (Wellens et al., 1990), France (Olivier and Devigne, 1983), Germany (Tanner, 1962), Finland (Kantero and Widholm, 1971), Russia (Bielicki, 1986), and Japan (Hoel et al., 1983); which interrupted ongoing secular trends. Late menarche was reported among girls in Bosnia (Tahirovic, 1998), where they had been subjected to severe war stresses in 1995 including exposure to bombing and shelling, death of close relatives, famine, and lack of sanitation and health services. Their estimated mean menarcheal age was 1.4 years greater than that of girls from control communities who were not exposed to the war. In Croatia (Prebeg and Bralic, 2000), Prebeg and Bralic reported a slight reversal in menarcheal trend of girls from the city of Sibenik during the 1991–1995 war, compared to the same population before the war. Although the menarcheal delay in some of these studies was attributed to food rationing around the time of puberty (van Noord and Kaaks, 1991), in the Croatia study the girls were not exposed to famine or collapses in the health or sanitation systems; rather, their exposure to the fear and psychosocial stress associated with war was prolonged for almost 4 years. The girls were as young as 7.5 years at the time when the most violent attacks occurred over the city. The authors suggested that the increase in menarcheal age was related to exposure to prolonged psychological stress during the war, even at relatively early ages. Further evidence for a maturation-delaying effect of early psychological stress is suggested by Widdowson's study of children from German orphanages who were successively exposed to a strict, forbidding, and otherwise cruel authority figure (Widdowson, 1951). Exposure to fear and humiliation caused by this person was associated with growth retardation in the orphans during a 6-month period, despite a concomitant increase in the availability of calories. Chronic psychological stress from living under conditions resembling those that exist during wars, could be a possible explanation for the observed association between nation-wide rates of homicide and age at menarche in Colombia, and may be consistent with the finding that the correlation with menarche was stronger for changes in homicide rates than changes in GDP; this is, that conditions other than purely material – such as prolonged psychological stress – could affect onset of menarche.[1]

Not all previous studies have found that early exposure to psychosocial stress is associated with delayed sexual maturation. In fact, several investigations suggest that direct exposure to stress during early infancy could be associated with earlier, rather than delayed, menarche (Whiting, 1965; Belsky et al., 1991; Kim et al., 1997; Hulanicka, 1999; Kim and Smith, 1999; Hulanicka et al., 2001; Chisholm et al., 2005; Teilmann et al., 2006; Belsky et al., 2007; Pesonen et al., 2008). It is plausible that the effect of stress on pubertal development depends on the intensity of the stressor, with moderate stressors resulting in earlier maturation and extreme psychosocial stress resulting in delayed development (Ellis, 2004). It is also possible that the effect of stress on sexual maturation depends on variability in the stress-induced reactivity of specific biological systems (Boyce and Ellis, 2005).

Comparing the secular trends in age at menarche between Colombia, Venezuela, and Brazil, it is tempting to speculate that chronic social and political unrest in Colombia, as evidenced by generalized violence, may have played a significant role in the differences observed, particularly with respect to Venezuela. Persistent warlike conditions in Colombia are likely to constitute the most salient difference in the historical processes that these two countries underwent during the late 20th century. It is challenging to explain the contrasting patterns in age at menarche through differences in economic growth alone: while the increase in GDP was rather parallel for the two countries from 1950 until the early 1970s, age at menarche had already decreased below 13 years in Venezuela by the 1950s. Data inaccuracies in our sample do not necessarily

[1] Delayed onset of reproductive maturity in girls who were chronically stressed by a violent environment during childhood would be consistent with Ellison's "bioassay" hypothesis (Ellison, 1990). According to this hypothesis, human females evolved an unconscious ability to assay the chronic qualities of the environment and accordingly adjust the timing of reproductive maturation to avoid the costs of reproducing under conditions that would not facilitate the offspring's health and survival. This programming of a set point for sexual maturation according to the quality of the early environment might be mediated through the effect of stress hormones, especially cortisol, on the hypothalamic–pituitary–ovarian (HPO) axis. Activation of stress–response systems through psychosocial stress could suppress the HPO axis, as suggested by studies on hypothalamic amenorrhea (Liu and Bill, 2008). Whether an analogous mechanism could also exist in pre-pubertal girls is not known.

explain these differences either, since our estimate of menarche for the 1980s is derived primarily from the students' direct recall of menarche rather than from their mothers' or sisters', which may be less accurate. In addition, it is likely that the average age at menarche for the whole country in the 1980s was even larger than that in our sample of relatively "privileged" college students from the capital city. If that is the case, the secular delay in age at menarche in Colombia may be even larger compared to other countries in the region. It is not possible to know from our data whether there were differences already in the menarche age of Colombian and Venezuelan girls in the 1930s and before.

The results need to be interpreted in light of several considerations. One has to do with the quality of the data. Information was collected from young women who reported their own age at menarche and also that of their sisters and mothers, when known. The student's report of their own age at menarche is likely to be a valid indicator of their actual age at menarche, as previously described in other settings (Bergsten-Brucefors, 1976; Koprowski et al., 2001) where the correlations between actual and recalled age at menarche after four years were 0.81 and 0.83, respectively. However, it is uncertain whether the mothers' or sisters' recall as transmitted to the women interviewed is as reliable, and whether the recall of this "secondhand" information was accurate. Of note, mean age at menarche of the participants' sisters born between 1970 and 1979, 13.1, was close to the self-reported age at menarche of students at the same university who were born during the same decade, 12.9, as reported by Mockus et al. (1995). Second, the sample size of some of the cohorts considered was small. Third, the group of women for whom information on age at menarche was available is representative of women entering the National University of Colombia and their families, but unlikely to be representative nation-wide.[2] Fourth, although we collected information on the students' socioeconomic status (SES), this information does not necessarily represent the SES of the students' mother or sisters around their age at menarche. We were therefore unable to examine whether the observed secular changes occurred preferentially in the poorer or in the better-off. Finally, ecological associations such as those currently presented could be biased by unmeasured confounding factors that are related both to age at menarche and to the rates of homicide. These include secular changes in other predictors of menarche, or household or other societal environmental conditions. Whether the association between nation-wide rates of homicide and age at menarche reported in this study is causal remains speculative.

In conclusion, rates of homicide associated with violent historical periods in recent Colombian history appear to be related to decelerations in the secular change of menarche. The correlation was higher when exposure to peaks of violence occurred during childhood. The relative contribution to physical maturation of psychosocial stress in the Colombian social and armed conflict, compared to material deprivation, deserves further study.

[2] For example, in the semi-urban town of El Yopal, mean age at menarche was 13.4 years among girls born in the 1980s (Carrillo, 2001). The poorest sectors of the Colombian population are unlikely to be well represented in our sample.

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