International Variability of Ages at Menarche and Menopause: Patterns and Main Determinants

FRÉDÉRIC THOMAS,[1] FRANÇOIS RENAUD,[1] ERIC BENEFICE,[2] THIERRY DE MEEÛS,[1] AND JEAN-FRANÇOIS GUEGAN[1]

Abstract The purpose of this study was to review published studies on the variability of age at menarche and age at menopause throughout the world, and to identify the main causes for age variation in the timing of these events. We first present a summary table including mean (or median) values of the age at menarche in 67 countries, and of the age at menopause in 26 countries. General linear models showed that mean age at menarche was strongly linked to the mean female life expectancy, suggesting that one or several variables responsible for inequalities in longevity similarly influenced the onset of menarche. A closer examination of the data revealed that among several variables reflecting living conditions, the factors best explaining the variation in age at menarche were adult illiteracy rate and vegetable calorie consumption. Because adult illiteracy rate has some correlation with the age at which children are involved in physical activities that can be detrimental in terms of energy expenditure, our results suggest that age at menarche reflects more a trend in energy balance than merely nutritional status. In addition, we found the main determinant of age at menopause to be the mean fertility. This study thus suggests that, on a large scale, age at menarche is mainly determined by extrinsic factors such as living conditions, while age at menopause seems to be mainly influenced by intrinsic factors such as the reproductive history of individuals. Finally, these findings suggest that human patterns cannot be addressed solely by traditional, small-scale investigations on single populations. Rather, complementary research on a larger scale, such as this study, may be more appropriate in defining some interesting applications to the practical problems of human ecology.

Menarche (first menstrual period) and menopause (end of menstruation) are the two major components in the reproductive life of women, since the interval between the two events determines the natural reproductive period during which females can procreate. Because these two biological traits have important cultural, social, and epidemiological implications, increasing attention has been recently

[1]CEPM, UMR CNRS-IRD 9926, 911 Avenue Agropolis B.P. 5045, Equipe 'Evolution des Systèmes Symbiotiques' 34032 Montpellier cedex 1, France.
[2]Laboratoire de Nutrition, Montpellier, France.

Human Biology, April 2001, v. 73, no. 2, pp. 271–290.

KEY WORDS: FERTILITY, NUTRITION, VARIABILITY

devoted by scientists to understanding the causes of age variations in the timing of these events. Although results are not always consistent from one study to another, several factors have been shown to significantly influence age at menarche and at menopause, such as genetic parameters (Danker-Hopfe and Delibalta 1990; Kaprio et al. 1995; Treolar et al. 1998), socioeconomic conditions (Belmaker 1982; Luoto et al. 1994), general health and life-style (Parazzini et al. 1992; Brown et al. 1996), nutritional status (Osteria 1983; Riley 1994; Simondon et al. 1997), seasonality (Boldsen 1992), physical activity (Malina 1983; Baker 1985), and altitude level (Beall 1983; Kapoor and Kapoor 1986; Gonzales and Villena 1996).

Mean ages at menarche and at menopause vary substantially between women across different countries or across different ethnic groups (Belitz 1977; Gray and Doyle 1983; Hunt and Newcomer 1984; Danker 1986; Ulijaszek et al. 1991; Flint 1997; Morabia et al. 1998). Reasons behind this international variability remain poorly understood, mainly because few comparative analyses have been conducted on such a large scale (but see Morabia et al. 1998). Most investigations of the relationships between ages at menarche and menopause and their causes have been studied on a small scale by social scientists, anthropologists, or public health epidemiologists. However, the variables affecting the timing of these events within populations do not necessarily explain differences between populations. In order to characterize patterns in the variation of ages at both menarche and menopause across populations, it is necessary to conduct examinations on large spatial and/or temporal scales (i.e., secular trends) in order to place the findings within a broader perspective. This approach is possible by adopting the techniques of "macroecology," which try to rise above the many details of local patterns to find a larger picture from which a kind of statistical order emerges (Lawton 1999).

In this study, we collected data on age at menarche and age at menopause in different countries from studies published worldwide. In order to understand the determinants of the timing of these events on this large spatial scale, we then attempted to regress the variability observed within these traits to various geographical, socioeconomic, cultural, and biological variables.

Material and Methods

Data. A literature search was performed for publications on age at menarche and age at menopause. All papers that displayed a measure (mean or median) for a given country of the timings of these events were retained for the analysis. When several values were given for the same country, we used the mean of these values. Some published data refer to a limited part of a population (e.g., a given city), and an important assumption we made is that they are representative of the country (but see the Discussion section). Only when conditions for parametric statistical analyses were violated (homogeneity of variances, error distribution), did we use log-transformed values (Zar 1996). The normality of error distribution was tested using Shapiro-Wilks statistics. Thus, age at menarche, mean fertility, and illiteracy rate values were log-transformed while age at menopause values were kept unchanged.

Socioeconomic and geographical parameters were obtained from the 1992 world population data sheet (Jones 1990) and from World Atlas v. 2.1.0©: (1) the female life expectancy at birth (in years), (2) the mean fertility (number of offspring born to a woman throughout the child-bearing years), (3) the per capita gross national product (GNP in US$ a year), (4) the population density (number of people per square kilometer), (5) the animal and vegetable calorie consumption per person and per day, (6) the mean latitude in degree and minutes, which refers to the value taken at the geographical center of each country, (7) the hemisphere of residency (northern is coded 1 and southern is coded 2). Data on mean female age at marriage were available from the Women's Indicators and Statistics data base (Wistat, version 3, United Nations publication). Adult illiteracy rates (expressed as a percentage) for each country were obtained from the United Nations Educational, Scientific and Cultural Organization.

Statistical Analyses. The possible sources of environmental heterogeneity at the largest spatial scale are extraordinarily various and thus cannot be simultaneously introduced in the models when attempting to explain the variation in ages at menarche and menopause. Thus, the contribution of different potential explanatory variables and their interaction terms to the dependent variables was first derived by general linear modeling (GLM) regressions with all independent variables retained in the final models (Zar 1996). In addition, minimal models were also selected after backward (and forward) stepwise elimination protocol. At each iteration, the variable showing the lowest partial regression coefficient with the dependent variable was removed from the model if its relationship was not significant at the 5% level (Zar 1996). When no variable could be removed from the model, that is to say when all variables are significant, the procedure was deemed finished. We used the tolerance option with a value of 0.05, which protects against constructing highly multicolinear models (Venables and Ripley 1994).

Age at Menarche. Since geographical factors (and/or their correlates) might influence the variation of age at menarche, we introduced in GLM regressions the mean latitude and the hemisphere of residency. To deal with the possible influence of demographic and economic variables, we also considered in the GLM regressions the population density and the per capita gross national product. Given the two kinds of values obtained for average age at menarche (i.e., mean or median), we controlled for this potential bias by introducing a dichotomous variable (named sampling bias, coded 1 for mean values and 2 for median values). The nonsignificance of this variable would indicate that we can pool mean and median values together, analyzing the entire data set simultaneously despite the heterogeneity of published data reporting average values. Finally, we introduced in the analysis the female life expectancy at birth, assuming that other living condi-

Table 1. Mean (or Median*) Age at Menarche and at Menopause in the Different Available Countries

Country	*Age at Menarche (in Years)*	*Reference*	*Age at Menopause (in Years)*	*Reference*
Algeria	14.3	Grassivaro-Gallo and Florio (1993)	—	—
Argentina	12.59	Zurlo de Mirotti et al. (1995)	—	—
Australia	13.0*	Morabia et al. (1998)	50.4	Walsh (1978)
Bangladesh	15.8	Riley and Khan (1993)	—	—
Belgium	13.0*	Vercauteren and Susanne (1984)	—	—
Britain	13.3	Mascie-Taylor and Boldsen (1986)	—	—
Cameroon	14.61	Biyong et al. (1985)	—	—
Canary Islands	—	—	48.6	Sosa Henriquez et al. (1994)
Chile	13.0*	Morabia et al. (1998)	50.0*	Morabia et al. (1998)
China	12.38*	Huen et al. (1997)	49.0*	Morabia et al. (1998)
Colombia	12.8	Pardo and Uriza (1991)	50.0*	Morabia et al. (1998)
Congo-Brazza	12.0	Samba (1982)	—	—
Congo-Kinshasa	13.83	Rashid-Tozin et al. (1984)	—	—
Cuba	13.01	Jordan-Rodriguez et al. (1980)	—	—
Czechoslovkia	14.6	Magursky et al. (1975)	51.2	Magursky et al. (1975)
Denmark	13.0	Helm and Grolund (1998)	—	—
Dominican Rep.	12.6	Mancebo (1990)	—	—
Egypt	13.2	Attallah (1978)	—	—
Finland	13.2	Dahlstrom et al. (1984)	51.0*	Luoto et al. (1994)
France	13.05*	Crognier and Tavares Da Rocha (1979)	52.0	Salat-Baroux (1980)

		(1979)		
East Germany	14.0*	Morabia et al. (1998)	—	—
Ghana	13.98	Adadevoh et al. (1989)	48.05	Kwawukume et al. (1993)
Greece	12.0	Pentzos-Daponte and Grefen-Peters (1984)	—	—
Guatemala	13.75	Khan et al. (1995)	—	—
Haiti	15.37	Barnes-Josiah and Augustin (1995)	—	—
Hungary	12.9	Dober and Kiralyfalvi (1993)	—	—
Iceland	13.06	Macgusson (1978)	—	—
India (Punjab)	14.31	Singh and Ahuja (1980)	44.6	Singh and Ahuja (1980)
Indonesia	13.0	Samsudin (1990)	50.5	Samil and Wishnuwardhani (1994)
Ireland	13.52	Hoey et al. (1986)	—	—
Israel	13.29	Belmaker (1982)	—	—
Italia	12.2	Zoppi (1992)	—	—
Jamaica	13.1	Jamaica National Family Planning (1988)	—	—
Japan	12.5	Nakamura et al. (1986)	49.3	Kono et al. (1990)
Kenya	14.4	Rogo et al. (1987)	—	—
Malaysia	14.2	Wilson (1985)	50.7	Ismael (1994)
Mexico	12.4	Garcia-Baltazar et al. (1993)	46.5	Garrido-Latorre et al. (1996)
Morocco	13.75*	Loukid et al. (1996)	—	—
Nepal (high altitude)	16.2*	Beall (1983)	46.8*	Beall (1983)
New-Zealand	12.9	St George et al. (1994)	—	—
Nicaragua	14.0	Guido et al. (1971)	—	—
Nigeria	15.0*	Morabia et al. (1998)	48.4	Okonofua et al. (1990)
Norway	13.2*	Nafstad et al. (1995)	—	—
Papua New Guinea	15.8	Groos and Smith (1992)	—	—
Peru	13.23	Soto-Caceres and Guevara-Servigon (1988)	—	—
Philippines	13.6	Zablan (1988)	48.0	Ramoso-Jalbuena (1994)

Table 1. Continued

Country	*Age at Menarche (in Years)*	*Reference*	*Age at Menopause (in Years)*	*Reference*
Poland	13.06	Laska-Mierzejewska et al. (1982)	—	—
Roumania	13.47	Stukovsky et al. (1967)	—	—
Russia	13.0	Iampol'skaia (1997)	49.0	Balan (1995)
Sardinia	12.78*	Floris et al. (1987)	—	—
Senegal	16.1	Simondon et al. (1997)	—	—
Somalia	14.78	Gallo (1975)	—	—
South Africa (black women)	—	—	49.2	Walker et al. (1984)
Southern Korea	13.9	Kim et al. (1986)	—	—
Spain	12.31	de la Puente et al. (1997)	—	—
Sri Lanka	13.5	Balasuriya and Fernando (1983)	—	—
Sudan	13.75	Attallah et al. (1983)	—	—
Sweden	13.09	Furu (1976)	50.9*	Hagstad (1988)
Switzerland	13.0	Morabia et al. (1996)	50.0	Morabia et al. (1996)
Tahiti	12.75*	Ducros and Ducros (1987)	—	—
Taiwan	13.6	Chow et al. (1997)	49.5	Chow et al. (1997)
Tanzania	15.21	Hautvast (1971)	—	—
Thailand	12.3	Piya-Anant et al. (1997)	50.3	Tungphaisal et al. (1991)
Turkey	13.28	Vicdan et al. (1996)	47.8	Carda et al. (1998)
United Arab Emirates	—	—	47.3	Rizk et al. (1998)
USA	12.8	Malina and Bouchard (1991)	51.3*	Kato et al. (1998)
Venezuela	12.68*	Farid-Coupal et al. (1981)	—	—
Yemen	14.4	Yemen Arab Republic Fertility Survey (1979)	—	—
Zambia	13.7	Katzarski et al. (1980)	—	—
Zimbabwe	13.5	Mbizvo et al. (1995)	—	—

tions able to influence the onset of menarche should also be reflected in life expectancy.

Age at Menopause. In order to assess the predictors of age at menopause, we considered two additional independent variables. Because age at menopause could be influenced by the length of active sexual life, we introduced in the GLM regressions the mean female age at marriage for each country, which roughly determines in most societies the beginning of reproductive life for females. Then, because there could be a trade-off between reproductive effort and length of sexual life (e.g., Westendorp and Kirkwood 1998; Thomas et al. 2000), we also introduced the mean fertility of each country. As before, we again considered the potential artefact exerted by the heterogeneity of published data in reporting age at menopause values (i.e., mean coded 1, and median coded 2).

Life Expectancy. When female life expectancy had a significant influence in the two previous analyses, we performed further analyses aimed at determining the possible causes behind this relationship. Among the numerous factors able to influence life expectancies, we considered those having a priori been identified potentially to affect the timing of reproductive events. Among these factors, we focused on two nutritional variables (animal and vegetable calorie consumption per person and per day) and adult illiteracy rate. Illiteracy rate is here used as an estimator of the mean level of energy expenditure resulting from physical activity. Indeed, adult illiteracy rate is usually positively correlated with child labor (Parker 1997; Psacharopoulos 1997) and with the nature of professional activities subsequently exerted by individuals (Rougerie and Courtois 1997). We first attempted to explain the variability in life expectancies by these variables. Following this analysis, variables relevant to explain life expectancy variations were used as predictors when attempting to explain the timing of reproductive events.

Analyses were performed using the S-Plus statistical package (MathSoft, Inc. 1999; Venables and Ripley 1994).

Results

Data on age at menarche and age at menopause were obtained for 67 and 26 countries, respectively (Table 1). Overall, the mean age of menarche is 13.53 years (SD ± 0.98) and the mean age of menopause is 49.24 years (SD ± 1.73).

Values for the independent variables used to explain the international variation in age at menarche were obtained for a subset of 58 countries out of the 67. Age at menarche was only related to female life expectancy (Figure 1A) when all potential influencing variables were considered (Table 2, $N = 58$, multiple adj. $R^2 = 0.535$, $p < 0.001$). Both backward and forward elimination procedures yielded similar results, i.e., single effect of female life span on age at menarche ($N = 58$, simple adj. $r^2 = 0.420$, $p < 0.00001$).

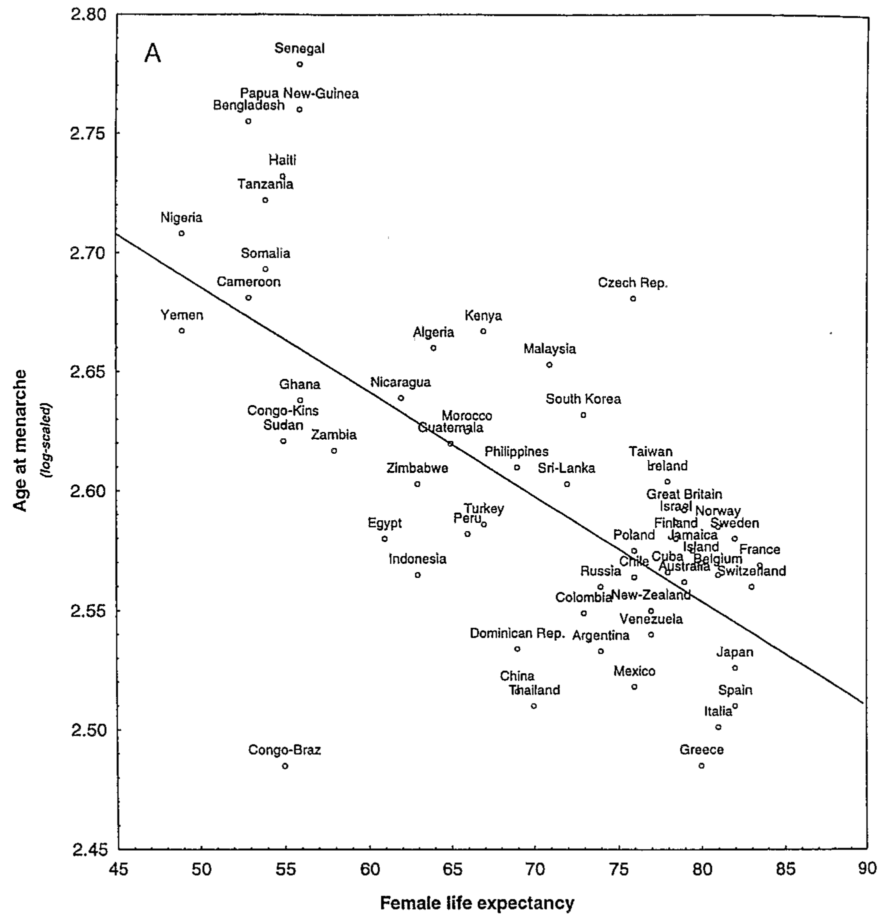

Figure 1. Relationships between age at menarche or age at menopause and their most relevant explanatory variables. **A,** Age at menarche and female life expectancy ($n = 58$, $r^2 = 0.434$, $y = -0.004x + 2.906$, $p < 0.00001$); **B,** Age at menarche and vegetable calorie consumption per person and per day ($n = 54$, $r^2 = 0.150$, $y = -0.002x + 2.781$, $p = 0.004$); **C,** Age at menarche and adult illiteracy rate ($n = 38$, $r^2 = 0.537$, $y = 0.033x + 2.539$, $p < 0.00001$); **D,** Age at menopause and fertility ($n = 23$, $r^2 = 0.442$, $y = -2.065x + 51.688$, $p = 0.0054$).

When performing a GLM procedure to analyze the variation in life expectancy across countries (total model not shown), we found that this trait was mainly explained by the adult illiteracy rate ($p < 0.00001$), GNP and vegetable calorie consumption being only marginally significant ($p = 0.072$ and $p = 0.076$, respectively). A backward stepwise procedure led to two equivalent minimal models in which illiteracy rate was highly significant in both cases, and vegetable

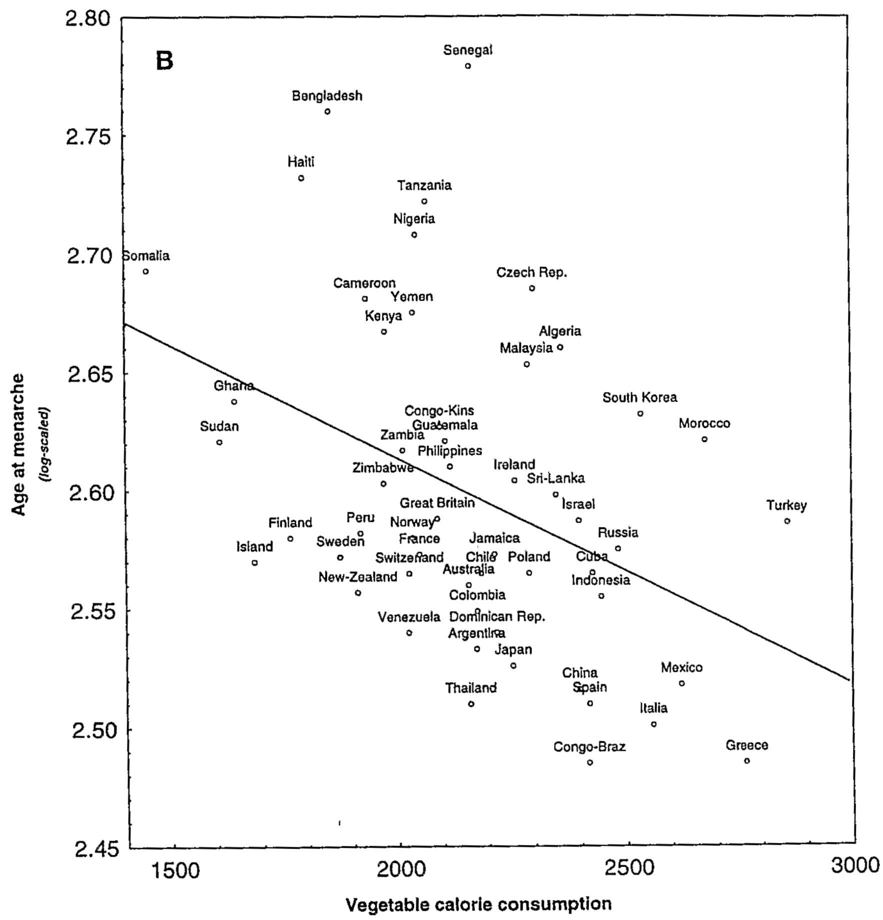

Figure 1. Continued

calorie consumption (Table 3, Model A, $N = 40$, multiple adj. $R^2 = 0.77$, $p < 0.0001$) or GNP (Table 3, Model B, $N = 41$, multiple adj. $R^2 = 0.79$, $p < 0.0001$) had an additional but exclusive contribution to the variance observed on female life expectancy.

Because GNP was already proposed as a possible predictor of age at menarche (see Table 2), we replaced the life expectancy variable by the two factors, i.e., illiteracy rate and vegetable calorie consumption, in the new explanatory model of age at menarche ($N = 37$, multiple adj. $R^2 = 0.57$, $p < 0.0001$). Both variables

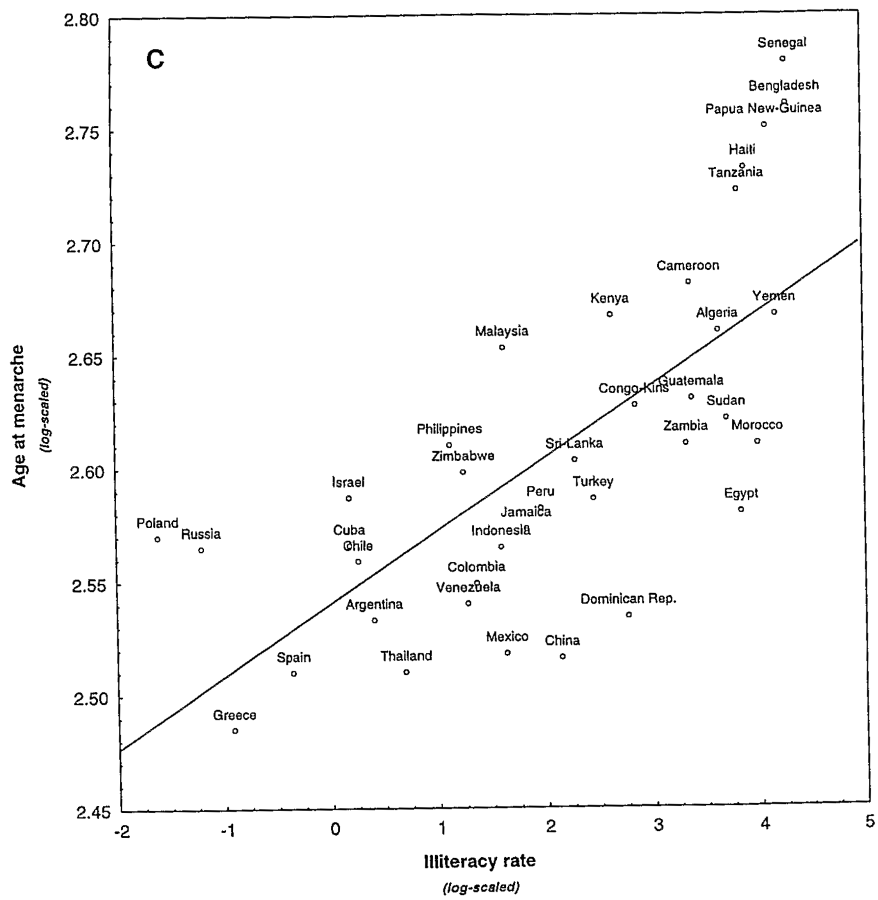

Figure 1. Continued

had a significant effect on age at menarche (Figures **1B** and **1C**; Table 4). Thus, at least two variables (i.e., vegetable calorie consumption and illiteracy rate) have the potential to influence living conditions at a level strong enough to modify both the onset of menarche and life expectancy.

Values for the independent variables used to explain the international variation in age at menopause were obtained for a subset of 21 countries. In a GLM model, only fertility had a significant effect (Table 5). Both backward and forward stepwise models yielded to similar results (Table 5; Figure **1D**).

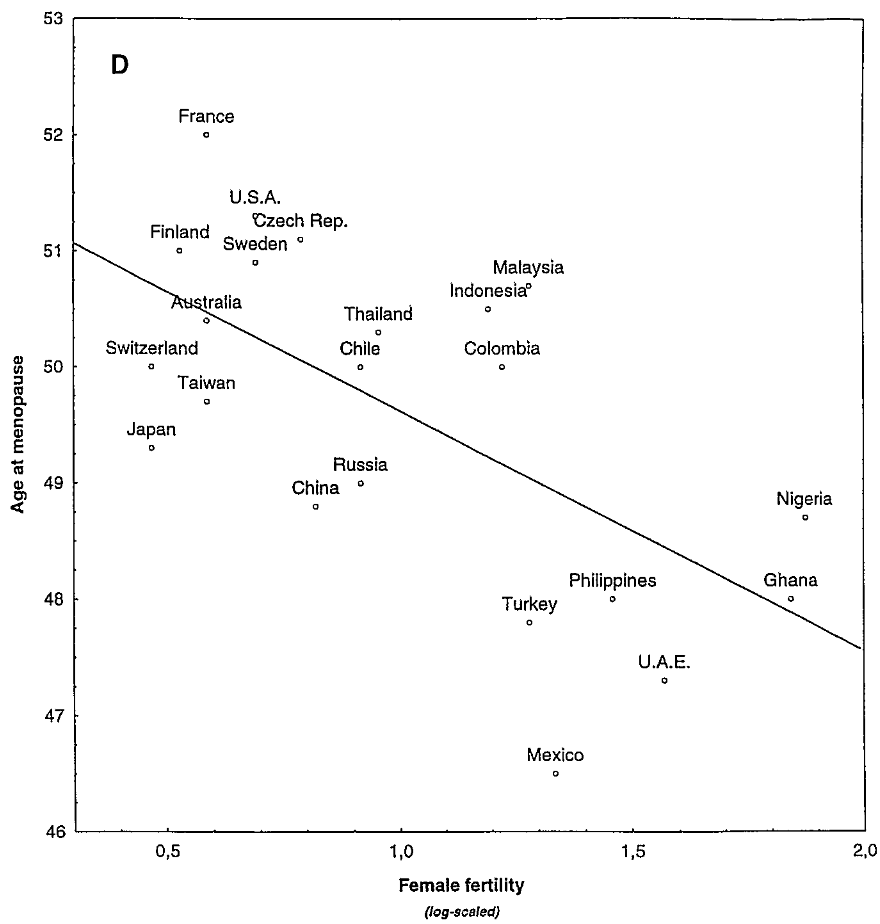

Figure 1. Continued

Discussion

It is frequently argued that comparative analyses using information from different sources may be inappropriate because data have been collected with different methods or they come from different sources. Although the argument is always applicable when no significant result is detected (i.e., data are not precise enough to detect a potentially significant result), it is unlikely to be relevant when significant trends are found, since a biological tendency has a priori no reason to be correlated to a background noise in the data set (Brown 1995; Rosenzweig 1995; Møller 1997; Lawton 1999).

Our results indicate that on a global scale, the age at menarche appears ear-

Table 2. General Linear Modelling for Age at Menarches (Log-Transformed) in Females across 58 Countries

	Parameter Estimate	*Standard Error*	*df*	*F*	*Pr (F)*
Intercept	1.415	0.195	1		
(1) Latitude	0.071	0.050	1	4.015	0.0525
(2) Female life expectancy	–0.008	0.005	1	54.031	**<0.0001**
(3) Population density	0.002	0.030	1	2.462	0.1251
(4) GNP	–0.013	0.034	1	0.063	0.8035
(5) Hemisphere	0.040	0.056	1	0.827	0.3690
(6) Sampling bias	–0.008	0.042	1	0.022	0.8826
(1):(2)	–0.001	0.001	1	1.850	0.1820
(1):(3)	0.004	0.007	1	0.253	0.6180
(1):(4)	0.005	0.005	1	6.672	0.0139
(1):(5)	0.019	0.009	1	0.998	0.3242
(1):(6)	0.008	0.007	1	1.485	0.2307
(2):(3)	0.001	0.001	1	0.087	0.7697
(2):(4)	0.001	0.001	1	2.257	0.1415
(2):(5)	–0.003	0.002	1	1.235	0.2736
(2):(6)	0.001	0.001	1	0.100	0.7539
(3):(4)	–0.005	0.006	1	2.057	0.1599
(3):(5)	0.010	0.010	1	0.404	0.5291
(3):(6)	–0.002	0.004	1	0.990	0.3262
(4):(5)	0.009	0.011	1	0.168	0.6844
(4):(6)	–0.003	0.005	1	0.590	0.4472
(5):(6)	0.010	0.010	1	1.176	0.2851

Note: Also given are the parameter estimate in regression, the standard error, the degree of freedom in analysis (*df*), the two-tailed probability value [Pr (*F*)] associated with the partial *F* statistics. The variable number 6, i.e. sampling bias, means that values of age at menarches have been categorized into mean values (coded 1) or median values (coded 2) in order to check for the influence of this sampling artefact on calculation. All two-way interaction terms of the expression (I):(J) have been introduced into the GLM procedure. Statistics in bold characters correspond to variable(s) retained in minimal models.

lier in countries where individuals experience the longest life expectancies. This result strongly suggests that the beginning of the capacity to reproduce in women is closely related to both biologically determined variables, i.e., genetic variability of life span, and culturally related variables, i.e., health and socioeconomic conditions. Previous studies have suggested this idea to explain the general decline in the menarcheal age in developed countries, concomitantly with the improvement of the living conditions during the last century (Nakamura et al. 1986; Tryggvadottir et al. 1994; Rees 1995). A close examination of our data reveals that at least two parameters reflecting living conditions influence variations of menarcheal age. Vegetable calorie consumption per person and per day has a small, but significant, influence on age at menarche, supporting the idea that good

Table 3. Two Alternative Minimal Linear Models for Explaining the Variability of Life Expectancy in Females across 40 (Model A) and 41 (Model B) Countries, Respectively

Model A

	Parameter Estimate	*Standard Error*	*df*	*F Value*	*Pr (F)*
Intercept	73.004	12.690	1		
(1) Illiteracy rate	−9.835	3.928	1	116.269	<0.0001
(2) Vegetable calorie	0.002	0.005	1	10.828	0.0022
(1):(2)	0.002	0.002	1	2.045	0.1613

Model B

	Parameter Estimate	*Standard Error*	*df*	*F Value*	*Pr (F)*
Intercept	67.466	7.884	1		
(1) Illiteracy rate	−9.611	2.532	1	140.332	<0.0001
(2) GNP	1.153	0.947	1	12.882	0.0009
(1):(2)	0.839	0.331	1	6.421	0.0656

Note: Abbreviations are as in Table 2. The expression (1):(2) represents for model A the interaction between the woman illiteracy rate and the consumption in vegetable calorie across countries, and for model B the interaction between the woman illiteracy rate and the global net incomes across countries.

nutritional conditions favor early menarche (Frisch 1982, 1985; Warren 1983; Haq 1984). Poor nutrition is known to alter the ratio of lean mass to body fat and to delay the onset of menarche (Baker 1985). The strongest factor remains, however, the illiteracy rate. Illiteracy rate is usually correlated with child labor (Parker 1997; Psacharopoulos 1997), which is itself frequently responsible for reduced growth and reduced development of children (Parker 1997). Indeed, child labor often results in physical activities that require a higher level of energy expenditure than that required at school. Excessive physical exercise is, for instance, known in athletic women to disrupt fat accumulation and, subsequently, to delay the onset of menarche (Baker 1985). Although further information would be necessary to address this point in detail, our results support the hypothesis that ovarian function reflects trends in energy balance, not merely nutritional status (Ellison 1990).

Age at menopause seems to be linked with variables other than those influencing life expectancy. The negative effect of the fertility variable on the age at menopause suggests the possible existence of reproductive costs in humans. For instance, early and high investments into reproduction may result in shorter longevity (Westendorp and Kirkwood 1998; Thomas et al. 2000). However, other studies have not found a significant relationship between fertility and age at

Table 4. General Linear Modeling for Age at Menarches (Log-Transformed) in Females across 37 Countries when the Female Life Expectancy Variable Was Replaced by the Mean Consumption in Vegetable Calorie and the Woman Illiteracy Rate per Country

	Parameter Estimate	*Standard Error*	*df*	*F Value*	*Pr (F)*
Intercept	12.532	109.561	1		
(1) Latitude	–0.285	6.709	1	6.694	0.0953
(2) Population density	–0.660	10.408	1	0.147	0.7090
(3) Hemisphere	11.008	107.301	1	1.931	0.1921
(4) GNP	–0.682	6.582	1	18.459	0.3513
(5) Sampling bias	–0.164	2.011	1	0.109	0.7470
(6) Vegetable calorie	–0.001	2.011	1	4.041	**0.0696**
(7) Illiteracy rate	0.475	6.530	1	11.954	**0.0054**
(1):(2)	0.839	0.331	1	0.343	0.5701
(1):(3)	–0.722	7.190	1	0.021	0.8883
(1):(4)	–0.044	0.003	1	2.171	0.1687
(1):(5)	0.055	0.044	1	1.635	0.2274
(1):(6)	<0.001	<0.001	1	0.072	0.7936
(1):(7)	0.055	0.444	1	5.006	0.0869
(2):(3)	–0.965	9.682	1	0.260	0.6200
(2):(4)	–0.008	0.027	1	1.235	0.2902
(2):(5)	–0.070	0.712	1	0.037	0.8514
(2):(6)	<–0.001	<0.001	1	1.390	0.2634
(2):(7)	–0.015	0.013	1	0.921	0.3577
(3):(4)	–0.965	9.682	1	2.538	0.1395
(3):(5)	—	—	—	—	—
(3):(6)	<0.001	0.002	1	0.127	0.7286
(3):(7)	–0.673	6.504	1	0.010	0.9231
(4):(5)	—	—	—	—	—
(4):(6)	<0.001	0.002	1	0.014	0.9092
(4):(7)	–0.007	0.012	1	0.490	0.4989
(5):(6)	—	—	—	—	—
(5):(7)	—	—	—	—	—
(6):(7)	<0.001	<0.001	1	0.595	0.4569

Note: Abbreviations are as in Tables 2 and 3. Statistics in bold characters correspond to variable(s) retained in minimal models.

menopause (e.g., Walsh 1978; Kirchengast 1992). More frequently, a significant positive relationship has been found between age at menopause and age at first birth (Stanford et al. 1987; Kirchengast 1992; Do et al. 1998). It is possible in our case that the negative relationship between fertility and age at menopause is in fact due to a positive relationship between the age at first birth and mean fertility (i.e., women with a high number of children are likely to have also started their reproductive life earlier). Although further information would be necessary to address this point, these findings support the idea that individual reproductive history influences the onset of the menopause.

Table 5. General Linear Modeling for Age at Menopause in Females across 21 Countries

	Parameter Estimate	*Standard Error*	*df*	*F Value*	*Pr (F)*
Intercept	24.840	114.685	1		
(1) Latitude	–4.570	28.444	1	0.163	0.6979
(2) Fertility	–23.323	54.067	1	15.685	**0.0055**
(3) Age at menarche	9.568	44.484	1	2.601	0.1509
(4) Sampling bias	–10.091	38.216	1	2.020	0.1982
(1):(2)	–1.664	1.889	1	0.680	0.4367
(1):(3)	2.165	11.190	1	0.188	0.6776
(1):(4)	0.158	0.920	1	0.248	0.6334
(2):(3)	8.207	19.306	1	0.001	0.9749
(2):(4)	–0.025	3.833	1	0.249	0.6329
(3):(4)	3.859	14.605	1	0.292	0.6057
(3):(5)	0.187	0.151	1	1.537	0.2550

Note: Abbreviations are as in Tables 2 and 3. The variable number 4, i.e., sampling bias, means that values of age at menopause have been categorized into mean values (coded 1) or median values (coded 2) in order to check for the influence of this sampling artefact on calculation. The introduction into modeling of the interaction term (3):(5) means that values of age at menarches (coded 3) have been corrected for by the influence (coded 5) of being mean or median values (see Table 2 for further details). Statistics in bold characters correspond to variable(s) retained in minimal models.

In conclusion, the factors explaining interpopulation differences of age variability in menarche and menopause in human females are poorly known. Our present results demonstrate that on a large spatial scale different factors may be responsible for the observed variation in age at menarche, whereas a single factor may explain the age at menopause. In fact, age at menarche seems to be closely related to extrinsic factors such as living conditions and, especially, the energy balance allocated to individuals. Conversely, age at menopause appears to be more sensitive to intrinsic parameters, such as the reproductive history of individuals. Most of the work in this branch of science has focused on studies of the variation of events related to reproduction within populations. Important work remains to be done in specifying the patterns that determine human reproductive traits; such studies on a larger scale may offer some alternative interesting issues.

Acknowledgments We thank F. Simondon and K. Simondon for comments on an earlier draft of the manuscript.

Received 17 September 1999; revision received 8 August 2000.

Literature Cited

Adadevoh, S.W., T.K. Agble, C. Hobbs et al. 1989. Menarcheal age in Ghanaian school girls. *Int. J. Gynaecol. Obstet.* 30:63–68.

Attallah, N.L. 1978. Age at menarche of schoolgirls in Egypt. *Ann. Hum. Biol.* 5:185–189.

Attallah, N.L., W.M. Matta, and M. El-Mankoushi. 1983. Age at menarche of schoolgirls in Khartoum. *Ann. Hum. Biol.* 10:185–188.

Baker, E.R. 1985. Body weight and the initiation of puberty. *Clin. Obstet. Gynecol.* 28:573–579.

Balan, V.E. 1995. Epidemiology of the climacteric period in a large city. *Akush. Ginekol. Mosk.* 3:25–28.

Balasuriya, S., and M.A. Fernando. 1983. Age at menarche in three districts in Sri Lanka. *Ceylon Med. J.* 28:227–231.

Barnes-Josiah, D., and A. Augustin. 1995. Secular trend in the age at menarche in Haiti. *Am. J. Hum. Biol.* 7:357–362.

Beall, C.M. 1983. Ages at menopause and menarche in a high-altitude Himalayan population. *Ann. Hum. Biol.* 10:365–370.

Belitz, B. 1977. A map on recent menarcheal age research in Europe. *Arztl. Jugendkd.* 68:81–92.

Belmaker, E. 1982. Sexual maturation of Jerusalem schoolgirls and its association with socio-economic factors and ethnic group. *Ann. Hum. Biol.* 9:321–328.

Biyong, M.A., H. Rikong, S.P. Nganga et al. 1985. A study of two reproductive parameters of cameroonian women. *Rev. Sci. Techn.* 2:55–61.

Boldsen, J.L. 1992. Season of birth and recalled age at menarche. *J. Bios. Sci.* 24:167–173.

Brown, D.E., T.V. Koenig, A.M. Demorales et al. 1996. Menarche age, fatness, and fat distribution in Hawaiian adolescents. *Am. J. Phys. Anthropol.* 99:239–247.

Brown, J.H. *Macroecology.* 1955. London, England: University of Chicago Press.

Carda, S.N., S.A. Bilge, T.N. Ozturk et al. 1998. The menopausal age related factors and climacteric symptoms in Turkish women. *Maturitas* 30:37–40.

Chow, S.N., C.C. Huang, and Y.T. Lee. 1997. Demographic characteristics and medical aspects of menopausal women in Taiwan. *J. Formos. Med. Assoc.* 96:806–811.

Crognier, E., and M.A. Tavares Da Rocha. 1979. Age at menarche in rural France. *Ann. Hum. Biol.* 6:167–169.

Dahlstrom, S., J. Viikari, H. Akerblom et al. 1984. Weight, height, and age at menarche of Finnish children in 1980. *Duodecim.* 100:838–848.

Danker, H. 1986. Menarcheal age in Europe. *Yearbook of Physical Anthropology* 29:81–112.

Danker-Hopfe, H., and K. Delibalta. 1990. Menarcheal age of Turkish girls in Bremen? *Anthropol. Anz.* 48:1–14.

De la Puente, M.L., J. Canela, J. Alvarez et al. 1997. Cross-sectional growth study of the child and adolescent population of Catalonia (Spain). *Ann. Hum. Biol.* 24:435–452.

Do, K.A., S.A. Treolar, N. Pandeya et al. 1998. Predictive factors of age at menopause in a large Australian twin study. *Hum. Biol.* 70:1073–1091.

Dober, I., and L. Kiralyfalvi. 1993. Pubertal development in south-Hungarian boys and girls. *Ann. Hum. Biol.* 20:71–74.

Ducros, J., and A. Ducros. 1987. Age at menarche in Tahiti. *Ann. Hum. Biol.* 14:559–562.

Ellison, P.T. 1990. Human ovarian function and reproductive ecology: New hypotheses. *Am. Anthropol.* 92:933–952.

Farid-Coupal, N., M. Lopez Contreras, and V. Mendez Castellano. 1981. The age at menarche in Carabobo, Venezuela with a note on the secular trend. *Ann. Hum. Biol.* 8:283–288.

Flint, M.P. 1997. Secular trends in menopause age. *J. Psychosom. Obstet. Gynaecol.* 18:65–72.

Floris, G., E. Murgia, G.M. Sanciu et al. 1987. Age at menarche in Sardinia (Italy). *Ann. Hum. Biol.* 14:285–286.

Frisch, R.E. 1982. Malnutrition and fertility. *Science* 21:1272–1273.

Frisch, R.E. 1985. Fatness, menarche and female fertility. *Persp. Biol. Med.* 28:611–633.

Furu, M. 1976. Menarcheal age in Stockholm girls. 1967. *Ann. Hum. Biol.* 3:587–590.

Gallo, P.G. 1975. The age at menarche in Somalia. *Ann. Hum. Biol.* 2:197–200.

Garcia-Baltazar, J., J.G. Figueroa-Perea, H. Reyes-Zapata et al. 1993. The reproductive characteristics of adolescents and young adults in Mexico City. *Salud Publica Mex.* 35:682–691.

Garrido-Latorre, F., E.C. Lazcano-Ponce, L. Lopez-Carrillo et al. 1996. Age of natural menopause among women in Mexico City. *Int. J. Gynaecol. Obstet.* 53:159–166.

Gonzales, G.F., and A. Villena. 1996. Body mass index and age at menarche in Peruvian children living at high altitude and at sea level. *Hum. Biol.* 68:265–275.

Grassivaro Gallo, P., and A. Florio. 1993. Female fertility in Algeria: Biodemographic and psychological aspects. *Genus* 49:115–134.

Gray, R.H., and P.E. Doyle. 1983. The epidemiology of conception and fertility. In *Obstetrical Epidemiology*, S.L. Barron and A.M. Thomson, eds. London, England: Academic Press, 25–59.

Gross, A.D., and T.A. Smith. 1992. Age at menarche and associated nutritional status variables in Karimui and Daribi census divisions of Simbu Province. *P.N.G. Med. J.* 35:84–94.

Guido, C., M. Garcia, and D. Navas. 1971. Analysis of 2746 treated abortions in the General Hospital of Managua. *Int. Surg.* 56:125–127.

Hagstad, A. 1988. Gynecology and sexuality in middle-aged women. *Women's Health* 13:57–80.

Haq, M.N. 1984. Age at menarche and the related issue: A pilot study on urban school girls. *J. Youth Adol.* 13:559–567.

Hautvast, J. 1971. Physical growth and menarcheal age in Tanzanian schoolchildren and adults. *Hum. Biol.* 43:421–444.

Helm, P., and L. Grolund. 1998. A halt in the secular trend towards earlier menarche in Denmark. *Acta Obstet. Gynecol. Scand.* 77:198–200.

Hoey, H., Cox, L. and Tanner, J. 1986. The age of menarche in Irish girls. *Irish Med. J.* 79:283–285.

Huen, K.F., S.S Leung, J.T. Lau et al. 1997. Secular trend in the sexual maturation of Southern Chinese girls. *Acta Paediatr.* 86:1121–1124.

Hunt, E. Jr., and N.W. Newcomer. 1984. The timing and variability of menarche, cumulative fertility and menopause: A symmetrical and parsimonious bioassay model. *Hum. Biol.* 56:47–62.

Iampol'skaia, I. 1997. Dynamics of puberty levels in girls of Moscow. *Gig Sanit.* 3:29–30.

Ismael, N.N. 1994. A study on the menopause in Malaysia. *Maturitas* 19:205–209.

Jamaica National Family Planning Board. 1988. Young Adult Reproductive Survey, Jamaica 1988 final report 153, p. 30.

Jones, H. 1990. *Population Geography.* 2nd ed. London, England: Paul Chapman Publishing.

Jordan-Rodriguez, J., A. Bebel Agua, M. Ruben et al. 1980. Pubertal development in Cuban adolescents. *Bol. Med. Hosp. Infant Mex.* 37:619–630.

Kapoor, A.K., and Kapoor, S. 1986. The effects of high altitude on age at menarche and menopause. *Int. J. Biometeorol.* 30:21–26.

Kaprio, J., A. Rimpela, T. Winter et al. 1995. Common genetic influences on BMI and age at menarche. *Hum. Biol.* 6:739–753.

Kato, I., P. Toniolo, A. Akhmedkhanov et al. 1998. A. Prospective study of factors influencing the onset of natural menopause. *J. Clinical. Epidemiol.* 51:1271–1276.

Katzarski, M., U.K. Rao, and K. Brady. 1980. Puberty in Zambian children. *Med. J. Zambian* 14:64–66.

Khan, A.D., D.G. Schroeder, R. Martorell et al. 1995. Age at menarche and nutritional supplementation. *J. Nutr.* 125:1090–1096.

Kim, S., J. Park, and K. Chung. 1986. A study on the menarche of Korean women. *Chung-Ang J. Med.* 11:343–350.

Kirchengast, S. 1992. Relations between fertility, body shape and menopause in Austrian women. *J. Bios. Sci.* 24:555–559.

Kono, S., Y. Sunawaga, H. Higa et al. 1990. Age of menopause in Japanese women: Trends and recent changes. *Maturitas* 12:43–49.

Kwawukume, E.Y., T.S. Ghosh, and J.B Wilson. 1993. Menopausal age of Ghanaian women. *Int. J. Gynaecol. Obstet.* 40:151–155.

Laska-Mierzejewska, T., H. Millice, and H. Piechaczek. 1982. Age at menarche and its secular trend in urban and rural girls in Poland. *Ann. Hum. Biol.* 9:227–233.

Lawton, J.H. 1999. Are there general laws in ecology? *Oikos* 84:177–192.

Loukid, M., A. Baali, M.K. Hilali. 1996. Secular trend in age at menarche in Marrakesh (Morocco). *Ann. Hum. Biol.* 23:333–335.

Luoto, R., J., Kaprio, and A. Uutela.1994. Age at natural menopause and sociodemographic status in Finland. *Am. J. Epidemiol.* 139:64–76.

Macgusson, T.E. 1978. Age at menarche in Iceland. *Am. J. Phys. Anthropol.* 48:511–514.

Malina, R.M. 1983. Menarche in athletes: a synthesis and hypothesis. *Ann. Hum. Biol.* 10:1–24.

Malina, R.M., and C. Bouchard. 1991. *Growth, Maturation and Physical Activity*. London, England: Human Kinetics Publishers (UK) Ltd.

Mancebo, P., C. Contreras, E. Perez, et al. 1990. Age of menarche of Dominican girls. *Arch. Domin. Pediat.* 26:7–11.

Mascie-Taylor, C.G.N., and J.L. Boldsen. 1986. Recalled age at menarche in Britain. *Ann. Hum. Biol.* 13:253–257.

Mbizvo, M.T., J. Kasule, V. Gupta et al. 1995. Reproductive biology knowledge, and behaviour of teenagers in East, Central and Southern Africa: The Zimbabwe case study. *Cent. Afr. J. Med.* 41:346–354.

Møller, A.P. 1997. Development stability and fitness: A review. *Am. Nat.* 149:916–932.

Morabia. A., and M.C. Costanza. 1998. The World Health Organization Collaborative Study of Neoplasia and Steroid Contraceptives: International variability in ages at menarche, first livebirth and menopause. *Am. J. Epidemiol.* 148:1195–1205.

Morabia, A., N. Khatchatrian, M. Bernstein et al. 1996. Reproductive characteristics of a population of urban Swiss women. *Acta Obstet. Gynecol. Scand.* 75:838–842.

Nafstad, P., B. Stray-Pedersen, M. Solvberg et al. 1995. Menarche and menstruation problems among teenagers in Oslo 1993. *Tidsskr Nor Laegeforen* 155:604–606.

Nakamura, I., M. Shimura, K. Nonaka et al. 1986. Changes of recollected menarcheal age and month among women in Tokyo over a period of 90 years. *Ann. Hum. Biol.* 13:547–554.

Osteria, T.S. 1983. Nutritional status and menarche in a rural community in the Philippines. *Philip. J. Nutr.* 36:150–156.

Parazzini, F., E. Negri, and C. La Vecchia. 1992. Reproductive and general lifestyle determinants of age at menopause. *Maturitas* 15:141–149.

Pardo, F., and G. Uriza. 1991. Study of adolescent pregnancy in 11 Colombian institutions. *Rev. Colomb. Obstet. Ginecolog.* 42:109–121.

Parker, D.L. 1997. Child labor. The impact of economic exploitation on the health and welfare of children. *Minnesota Med.* 80:55–55.

Pentzos-Daponte, A., and S. Grefen-Peters. 1984. Age of the menarche of girls in Thessaloniki, Greece. *Anthropol. Anz.* 42:219–225.

Piya-Anant, M., S. Suvanichchati, M. Bharscharirl et al. 1997. Sexual maturation in Thai girls. *J. Med. Assoc. Thai* 80:557–564.

Psacharopoulos, G. 1997. Child labor versus educational attainment: Some evidence from Latin America. *J. Pop. Econom.* 10:377–386.

Ramoso-Jalbuena, J. 1994. Climacteric Filipino women: A preliminary survey in the Philippines. *Maturitas* 19:183–190.

Rashid-Tozin, R., I. Mugeni, L. Shango et al. 1984. Average age at menarche of Zairian girls in Kinshasa, Zaire. *Ann. Soc. Belge Med. Trop.* 64:69–74.

Rees, M. 1995. The age of menarche. *Orgyn* 4:2–4.

Riley, A.P. 1994. Determinants of adolescent fertility and its consequences for maternal health, with special reference to rural Bangladesh. *Ann. New York Acad. Sci.* 709:86–100.

Riley, A.P., and N.U. Khan. 1993. Age at first marriage for women in Matlab, Bangladesh: The role of biological and social determinants. Unpublished report presented at the Annual Meeting of the Population Association of America, Cincinnati, Ohio, April, pp. 13.

Rizk, D.E., A. Bener, M. Ezimokhai et al. 1998. The age and symptomatology of natural menopause among United Arab Emirates women. *Maturitas* 29:197–202.

Rogo, K.O., R.K. Oniang'o, and L.A. Muruli. 1987. Menarche in African girls in some post-secondary institutions in Kenya. *East Afr. Med. J.* 64:745–750.

Rosenzweig, M.L. 1995. Species diversity in space and time. Cambridge, England: Cambridge University Press.

Rougerie, C., and J. Courtois, 1997. A step toward adulthood: The first real job. *Population* 52: 1297–1327.

Salat-Baroux, J. 1980. The menopause and its problems. *Sem. Hop.* 56:1343–1345.

Samba, J. 1982. Report of socio-demographic survey. Unpublished report (Projet FNUAP CNG/MCH/001), pp. 31.

Samil, R.S., and S.D. Wishnuwardhani. 1994. Health of indonesian women city-dwellers of perimenopause age. *Maturitas* 19:191–197.

Samsudin. 1990. The age of menarche as related to physical growth of junior high school girls in Jakarta. *Paediatr. Indones.* 30:254–260.

Simondon, K.B., I. Simon, and F. Simondon. 1997. Nutritional status and age at menarche of Senegalese adolescents. *Ann. Hum. Biol.* 24:521–532.

Singh, L., and S. Ahuja. 1980. An estimation of reproductive performance in the women of Punjab. *Anthropl. Anz.* 37:266–270.

Sosa Henriquez, M., M.C. Navarro Rodriguez, J.M. Liminana Canal et al. 1994. Age of menopause onset in Canary Islands women. *Rev. Sanid. Hig. Publica* 68:385–391.

Soto-Caceres, V.A., D. Guevara-Servigon, Chiclayo. 1988. Peru: Sexuality and family planning in women of different socioeconomic status. *Persp. Inter. Planif. Famil.* 29–32

St. George, I.M., S. Williams, and P.A. Silva. 1994. Body size and the menarche: The Dunedin Study. *J. Adolesc. Health* 15:573–576.

Stanford, J.L., P. Hartge, L.A. Brinton et al. 1987. Factors influencing the age at natural menopause. *J. Chron. Dis.* 40:995–1002.

Stukovsky, R., J.A. Valsik, M. Bulai-Stirbu. 1967. Family size and menarcheal age in Constanza, Roumania. *Hum. Biol.* 39:277–283.

Thomas, F., A.T. Teriokhin, F. Renaud et al. 2000. Human longevity at the cost of reproductive success: Evidence from global data. *J. Evol. Biol.* 13:409–414.

Treolar, S.A., K.A. Do, and N.G. Martin. 1998. Genetic influences on the age at menopause. *Lancet* 35:1084–1085.

Tryggvadottir, L., H. Tulinius, and M.A. Larusdottir. 1994. Decline and a halt in mean age at menarche in Iceland. *Ann. Hum. Biol.* 21:179–186.

Tungphaisal, S., V. Chandeying, S. Sutthijumroon et al. 1991. Postmenopausal sexuality in Thai women. *Asia Oceania J. Obstet. Gynaecol.* 17:143–146.

Ulijaszek S.J., E. Evans, and D.S. Miller. 1991. Age at menarche of European, Afro-Caribbean and Indo-Pakistani schoolgirls living in London. *Ann. Hum. Biol.* 18:167–175.

Venables, W.N., and B.D. Ripley. 1994. *Modern Applied Statistics with S-Plus.* Berlin, Germany: Springer Verlag.

Vercauteren, M., and C. Susanne. 1984. Current age of the menarche in Belgium. *Anthropol. Anz.* 42:211–217.

Vicdan, K., S. Kukner, T. Dabakoglu et al. 1996. Demographic and epidemiologic features of females adolescents in Turkey. *J. Adolesc. Health* 18:54–58.

Walker, A.R., B.F. Walker, J. Ncongwane et al. 1984. Age at menopause in black women in South Africa. *Br. J. Obstet. Gynaecol.* 91:797–801.

Walsh, R.J. 1978. The age of the menopause of Australian women. *Med. J. Aust.* 2:182–215.

Warren, M.P. 1983. Effects of undernutrition on reproductive function in the human. *Endocr. Reviews* 4:363–377.

Westendorp, R.G.J., and T.B.L Kirkwood. 1998. Human longevity at the cost of reproductive success. *Nature* 396:743–746.

Wilson, C.S. 1985. Malay reproductive practices in a modernizing village: An update. Unpublished report presented at the annual meeting, American Anthropological Association, Washington, p. 11.

Yemen Arab Republic Fertility Survey. 1979. Vol. 1: Survey Design and Findings. Sanaa, Yemen, Central Planning Organization, p. 178.

Zablan, Z.C. 1988. Proximate determinants of Philippine fertility: 1983 levels and patterns. *Philipp. Pop. J.* 4:81–102.

Zar, J.H. 1996. Biostatistical Analysis. 3rd version. Upper Saddle River, NJ: Prentice-Hall.

Zoppi, G. 1992. Physiology of pubertal maturation. *Pediatr. Med. Chir.* 14:375–379.

Zurlo de Mirotti, S.M., A.M. Lesa, and M. Barron de Carbonetti. 1995. Age of menarche. Secondary sex characteristics. Interrelation. Secular trend. *Rev. Fac. Cien. Med. Univ. Nac. Cordoba* 53:7–15.