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THE BIOLOGICAL STANDARD OF LIVING IN CHINA DURING THE 20TH CENTURY: EVIDENCE FROM THE AGE AT MENARCHE

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Abstract*

This paper uses the mean age at menarche as an indicator of changes in the standard of living in China during the tumultuous 20th century. It discusses the difficulties of using this indicator in terms of the quality of the available data, the processing the basic data, and the interpretation of the results. The paper finds that the mean age at menarche in China stagnated at 16 to 17 years for women born during the 1880s-1930s, although it also finds decreases in some urban areas, such as Beijing and Shanghai, indicative of an improving standard of living. The mean age at menarche increased for 1940s birth cohorts, in part due the negative effects of the China-Japan war and the civil war in the 1940s, but also the famine of 1959-1962 that affected these cohorts during puberty. The mean age at menarche decreased in a sustained way for women born during the 1950s to the early 2000s, to a level of 12.1 in 2000-03. This decrease preceded the acceleration of economic growth in the 1980s. Increased educational attainment since the 1940s explains much of the decrease in the age at menarche, ahead of improvements in nutrition, hygiene and healthcare.

Keywords: China, living standards, human growth, anthropometrics, menarche
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The Biological Standard of Living in China during the 20th Century: Evidence from the Age at Menarche

1. Introduction

The age at menarche (AM) is an important marker of human development. Improved nutrition and a lower disease burden are associated with earlier menarche in populations of women (Prentice *et al.* 2010). Secular trends in AM can therefore serve as indications of changes in the standard of living of a population. Several studies analysed a downward trend in AM and have associated this with improved living standards in the United States and Europe (Wyshak and Frisch 1982; Onland-Moret *et al.* 2005), and in Japan (Hoshi and Kouchi 1981; Tomobe 2007).

China experienced high rates of economic growth since its government proposed economic reforms in 1978 and started implementing them in 1980. Following three decades of low economic growth during the 1950s-1970s, the country's real per capita GDP increased almost 8 times between 1980 and 2010.[1] At the same time, income inequality increased significantly in China (Xie and Zhou 2014), indicating that the social benefits associated with economic growth were not widely shared. Also, doubts exist about the accuracy of China's national accounts data, particularly for the years before China stopped using the Material Product System in 1992 (Wu 2007; He 2010). In addition, no less than 40 to 45% of China's economic growth took the form of fixed capital formation on the expenditure side (Ding and Knight 2011), rather than household and public expenditure on items associated with changes in anthropometric indicators, such as food consumption, healthcare, and medical services. In other words, we can not necessarily assume that GDP per capita is a broad indicator of the average living standard in China.

This makes it relevant to probe alternative indicators of long term changes in the standard of living in China to establish whether changes in recent decades are a continuation of past trends or a new development since 1980. Some studies already used anthropometric data, particularly average heights of children and adults, to shed systematic quantitative light on trends in welfare and living standards in China (Morgan 2000, 2004, 2014; Ward 2013). This study uses an alternative anthropometric indicator to establish whether and to what extent high economic growth in China since 1980 corresponds with an increase in the biological standard of living as measured by earlier AM, and to what extent available data on menarche allow an analysis of longer-term changes in living standards. This alternative indicator is worth analysing because height and menarche are not necessarily determined by the same factors. For example, in the case of Indonesia, Sohn (2017) found that secular change in AM was more strongly related to GDP per capita than average height.

[1] Calculated from the Maddison Project Database 2013, https://www.rug.nl/ggdc/historicaldevelopment/maddison/releases/maddison-project-database-2013

The paper also explores the possible reasons for the long-term changes in AM, particularly its possible association with changes in hygiene and healthcare during childhood and adolescence, and possibly changes in food consumption (Zhou *et al.* 2014; Qi and Niu 2015). Several studies associated earlier AM with negative health implications, such as breast cancer (Collaborative Group 2012), obesity (Sohn 2016), and cardiovascular disease (Prentice and Viner 2013). Hence, decreasing AM is not necessarily an indication of improved health. However, such maladies are generally diseases associated with affluence. As earlier menarche has in broad terms been linked with factors such as more and better nutrition, a lower disease burden, better health care, and a lower physical workload in childhood, it should not be controversial that these conditions are associated with higher standards of living.

The next section discusses the data on relatively small and regional studies of the mean or median age at menarche (MAM) that exist for China for girls born during the 100 years from 1882 to 2002, and the broad impressions that can be gleaned from those scattered data. Section 3 explains the two nation-wide datasets that we have used in this paper to assess trends of MAM during 1925 to 2003, and compares our estimates with those of other studies that used other national data sets, but for shorter time periods. Section 4 then analyses the time trends in the context of changed biological living standards in China, particularly changes in education, health care and food supply.

2. Changes in the age at menarche of Chinese women

Various studies demonstrated that MAM decreased across countries that experienced economic growth and improved levels of nutrition and general health. In European countries, MAM decreased by approximately 4 months per decade from the 1830s to the 1950s, after which the decrease decelerated (Marshall and Tanner 1986). Studies of Asian countries, particularly Japan, South Korea and Indonesia, have demonstrated the same, albeit that they found a much faster decrease in MAM. For example, in the case of South Korea the decrease was approximately 8 months per decade (Sohn 2017). The MAM in several Asian countries at advanced levels of development are now among the lowest in the world, such as in Hong Kong where it reached 11.5 years in the 1990s (So and Yen 1992; Tang *et al.* 2003).

In China, data from the quinquennial National Survey on the Constitution and Health of Students (NSCHS), also known as the National Physical Fitness and Health Survey, are often used to demonstrate that MAM has decreased since the 1980s, although not yet at the level in Hong Kong (Song *et al.* 2014, 2015). However, the outcomes of the early NSCHS rounds are biased downwards due to incomplete primary school and low high school enrolments in China, as we explain below.

Appendix Table A1 comprises the outcomes of almost all published studies that contain estimates of MAM in China. The earliest data are from anthropological and medical studies based on small samples of women in local areas. Most of the early studies were conducted in

the first half of 20th century in relatively affluent urban areas, particularly Beijing, Shanghai and Guangzhou. The outcomes of all such occasional and regional studies are summarised by average birth years in Figure 1.

[Figure 1 about here]

The first estimate of MAM in China of 16.5 years was made in 1899 on the basis of an occasional survey of 50 women by the physician at the French embassy in Beijing (Matignon 1899). Its outcome for women born during the 1880s is relatively high, but is comparable to that of 16.5 among ethnic Chinese women surveyed in the 1870s in Cholon (Ho Chi Minh City, Vietnam) (Mondiere 1882: 489), 16.2 to 16.7 for women surveyed in Taiwan around 1905 (Yamasaki 1909: 1302-1303), 17.1 for Chinese women born in Tai'an city (Shandong province) in the 1890s (Qi 2014), and 16.5 for women born in Anhui and across China in the mid-1940s (Graham *et al.* 1999; Wu *et al.* 2000; Lewington *et al.* 2014;).

The earliest estimates of consistent changes in MAM was based on the recollections of women from Jiangsu and Zhejiang provinces attending hospitals in Shanghai, Ningbo and Nanjing. The result for the 1877 birth year of 15.3 years was based on a sample of just 8 women, but the sample size was higher for later birth cohorts and the study reveals a gradual decrease in MAM to 14.1 for birth year 1920 (Tao and Shu 1937: 300).

On the basis of the results of occasional surveys conducted in 1925 in Guangdong and in 1960 in Hebei province, as well as the outcomes of the 1980-81 and 1985 national surveys (see Table A1), we may infer that MAM in rural parts of China was 5 to 15% higher than in urban Beijing. Hence, MAM for women born during the early 1880s in China as a whole may have been 17 to 17.5 years. This is not unreasonably high. Firstly, Wood (1994: 419) lists MAMs of 18.0-18.6 in rural highlands of Papua New Guinea and high altitude Nepal in the 1960s-1980s. Secondly, such approximate numbers are comparable with MAM in less-developed parts of Europe in the early 19th century, particularly in Norway, Denmark and Switzerland (Danker-Hopfe 1986: 34-38; Helm 1984; Lehmann and Scheffler 2016).

Several occasional studies based on small samples and with only regional significance were yielded MAMs for birth years during the 1930s-1960s, as Figure 1 shows. Together with the 16.5 estimate of MAM in Beijing for women born in the 1880s, and the associated estimate of 17 to 17.5 for China as a whole, they suggest a decrease. However, we cannot scrutinise the original data collected in Beijing around 1899, and the sample of 50 was relatively small. On the other hand, a decrease would be consistent with the fact that average heights of adult men employed at government enterprises and agencies across China increased from 166.2 for birth cohorts of the 1880s to 168.0 for those born in the 1920s (Morgan 2004: 210). This was confirmed with another data set that saw adult male heights of birth cohorts of the early 1880s of 164.1 cm increase considerably to 170.6 cm for those born in the early 1910s, and of Chinese women from 155.9 cm in the early 1880s to 159.6 cm in

the early 1920s (Ward 2013: 500). It would also be consistent with real wages in Beijing almost doubling from the early 1870s to the early 1900s (Allen *et al.* 2011: 27). The significant decrease of MAM from the 1880s to the 1900s in Figure 1 may therefore point to a similar increase in the biological living standards in China, or at least in Beijing.

MAM of women born from the 1900s to the mid-1930s and surveyed in the cities of Beijing, Shanghai, Guangzhou, Wuchong, Nanjing, Suzhou and Changsha, appears to be broadly within a band of 14 to 15. The longitudinal estimates from Shanghai in Figure 1 demonstrate that MAM decreased from 15.0 for women born in the mid-1930s to 14.5 for those born in the city in the mid-1940s. The occasional regional studies, as well as the longitudinal cases of Tai'an city (Shandong province), the Pudong suburb of Shanghai, rural Anhui province, and Zhejiang and Jiangsu provinces all suggest that MAM decreased significantly for women born after the 1940s, rather than after the 1970s as data on economic growth would suggest.

No such regional studies were published during the very testing years between 1963 and 1977 in China. Nationally representative surveys with data on AM were not conducted until the late-1970s. Renewed interest in studying AM was possibly related to concerns about overpopulation in China and preparations in 1978-1979 for a new demographic program, known as the 'one-child policy'. Preparations may have required up-to-date and more representative indications of AM, and also fecundity, nuptiality and fertility. A large National Conference on Regional Obstetrics and Gynaecology in Jinan (Shandong Province) in January 1978 for the first time brought together conference participants who presented MAM estimates based on administrative data from different parts of the country (Zhongshan Medical College 1982: 790).

In that context, Ye *et al*. (1981) published the results of their 1963-64 Beijing survey into MAM, 15 years after they conducted it. And Zhang *et al.* (1984) led the 'National Coordinating Group on Menstrual Patterns' to publish results from the first 1978-80 large national survey involving more than 130,000 girls and young women. This survey became known as the 1979 NSCHS. The methodology of this large survey was updated, and the NSCHS was repeated in 1985, 1991, 1995, 2000, 2005 and 2010 (Lin *et al.* 1992; Song *et al.* 2014, 2015).

Independently, Cui *et al.* (1982) published results from their 1980-81 occasional national survey among 11,600 girls and young women across 13 ethnic groups in different parts of the country. It revealed for the first time very significant differences in MAM across urban and rural regions in the whole of China, with MAM in Beijing being much lower than in other parts of the country. The outcomes of the much larger NSCHS rounds later confirmed this. Together they pointed to a significantly uneven geographic distribution of AM across provinces and between rural and urban areas.

Most MAM estimates from occasional regional studies and from NSCHS are based on the status quo (SQ) methodology. The NSCHS rounds now allow the analysis of trends during 1979-2010, or 30 years. But they do not allow a retrospective reconstruction of

historical trends, nor an answer to the question whether change in MAM since 1979 was a continuation of time trends before the 1980s, or a reflection of new phenomena that emerged since 1979. This question can be addressed on the basis of surveys or administrative data sets that use the recollection (Rec) methodology.

The outcomes of Rec-based studies may be biased for two reasons; (a) selective memory among surveyed women, and (b) sample survival. The first issue has been researched extensively and has some ground in theory. However, empirical research suggests that both methods yield consistent results (Henneberg and Louw 1995; Lehman and Scheffler 2016: 710-711). After all, menarche is a noted biomarker in life that few women fail to recall. In the case of China, Cui *et al.* (1982) used both the SQ and Rec methods. Appendix Table A1 shows that the results are slightly different, but for large samples the difference is minimal and certainly not big enough to discredit the Rec methodology. The second issue relates to the fact that only physically healthy women survive in old age. Their lifetime physical health is correlated with relatively low AM in their age cohorts, and their survival rates reduce the standard deviation. This is a likely reason why Rec-based surveys find a flattening of MAM back in time, such as for Korea in the 1930s around the age of 16.5 (Sohn 2017).

Outcomes of several Rec-based surveys conducted in China have become available in recent years. They are either based on archived registration data from hospitals and women's health clinics, or on large surveys. The first was a modest 1988 national survey among 27,655 women (Wang and Murphy 2002). It was followed by the 1993 survey among 12,726 women in two rural counties in Anhui province (Graham *et al.*1999), which is shown in Figure 1, and the 1997 National Demography and Reproductive Health Survey among 14,679 women (Wu *et al.* 2000). Lyu *et al.* (2014) used the 1991-2008 collection of the health records with retrospective menarche data of 1.2 million women in Zhejiang and Jiangsu provinces, and Chen, Wang and Mi (2014) used the 1948-1954 hospital records of 3,608 women in Beijing. Other retrospective surveys were conducted in 2000 among 31,955 women in Shanghai (Wu *et al.* 2014), and in 2004-2008 among more than 300,000 women nationally, which is now the China Kadoorie Biobank at the University of Oxford (Lewington *et al.* 2014).

Interpretation of these retrospective estimates of MAM by birth year is not straightforward, as we discuss below. Nevertheless, the outcomes indicate a significant decrease in MAM for cohorts of women born since the 1940s, as Figure 1 shows for several regional studies. This suggests that studies using the SQ methodology since the 1980s observed a trend of improving living standards in China that started well before economic growth accelerated in the 1980s. This will be discussed below.

The databases mentioned above have been the basis of some studies into time trends of MAM in China. But most established such time trends for short periods of 25 to 30 years, and most established trends that apply to particular regions, rather than China as a whole. A few examples may explain the difficulties of using the outcomes of such studies. An example of SQ-based studies is Ma *et al.* (2009), which employed a sample (collected in October 2003-June 2005) of apparently healthy girls drawn from kindergartens to secondary schools in nine

main cities of China. The authors compared MAM from this data set with MAMs estimated on the basis of the NSCHS survey rounds since 1979 and found that MAM decreased from 13.5 in 1979 to 12.3 in 2003-2005. However, their sample was collected from nine main cities only, while the NSCHS covered both urban and rural areas, so that the comparisons of the data results in an overestimation of the rate of decrease in the trend.

Ohsawa *et al.* (1997) accommodated this concern and considered the downward trend in MAM for just Beijing, because there had been relatively more investigations in the city than in other areas. Nevertheless, the significant regional imbalance of economic growth implies that Beijing witnessed the benefits of economic growth more profoundly than other parts of the country. Thus, MAM trend they observed is not representative of China as a whole. Moreover, just like Figure 1, the studies used by Ohsawa *et al.* (1997) to approximate trend varied in their sampling schemes. This may have imposed limitations on the comparability of their outcomes.

Graham *et al.* (1999) is an example of a Rec-based study. It collected information regarding secular changes in AM from women residing in two rural counties of – as the study notes – a little-known region in Anhui Province. MAM was measured in a consistent manner, and revealed a downward trend, as Figure 1 shows. However, the survey region was too small to be representative of a national trend in AM.

Thus, the challenge for this paper is to provide evidence for long-term changes in MAM on the basis of more representative national data that have been collated in a manner that is more consistent than across the regional studies. The purpose is to augment the currently available estimates in order to confirm these estimates and extend them to earlier and later years. For that purpose, the paper uses two datasets that cover the birth years 1925-1974 and 1975-2003. Our interest is in identifying and understanding the long-term trend in AM at a national level.

3. Materials and methods

Apart from the outcomes of research projects that covered short periods, the main datasets used here are those of the China Health and Retirement Longitudinal Study (CHARLS) for older women born 1925-1974 and the China Health and Nutrition Survey (CHNS) for younger women born 1975-2003. The sampling schemes and geographical coverages differed between both surveys. Nevertheless, in combination they yield statistically accurate and nationally representative indications of trends in MAM.

CHARLS facilitates research into the elderly in China and contains panel data on people aged 45 and over. It is organised by the Institute of Social Science Survey at Peking University, and aims to collect data from a nationally representative sample of Chinese residents. The first baseline survey was fielded in 2011-12, covering about 17,500 individuals in about 10,000 households in 450 villages or resident committees in 150 counties or districts. Respondents were drawn at the county, neighbourhood, household, and respondent-level in a

way to make the sample nationally representative. The second and third rounds of CHARLS were conducted in 2013 and 2014 respectively, but we used only the first and second waves because they contained a variable of age at menarche.

CHARLS contains data from 9,151 women, most of them aged or elderly, which for the purpose of this paper implies a large number of observations of AM for women born as far back as the 1920s. CHARLS interviewers asked the year or age when the respondents experienced menarche. In the first round, the year at menarche variable (a four digit number) contained age at menarche (a one or two digit number), and the age at menarche variable contained the year at menarche. We judiciously used these two variables for further analysis.[2] The second round did not have this problem, and we added only new respondents in the second wave to those in the first wave. We restricted ages at menarche to 8-19 year-olds and grouped birth years in five-year intervals. To improve precision in MAM measurement, we selected birth year groups with at least 100 observations. Birth years ranged from 1925 to 1974, and the sample size was 8,583.

We augment the CHARLS data with observations from the China Health and Nutrition Survey (CHNS). This is an ongoing longitudinal survey and an international collaborative project between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention in Beijing. CHNS aims to examine the effects of the health, nutrition, and family planning policies and programs implemented by national and local governments and to examine how the social and economic transformation of Chinese society is affecting the health and nutritional status of its population. It started in 1989 with about 16,000 individuals, and it has since followed respondents irregularly; the last survey year used in this study was 2011. The survey covers nine provinces, which were selected so as to vary in geography, economic development, public resources, and health indicators. The sampling scheme involved a multistage, random cluster process to draw the samples surveyed in each province. Thus, although the survey does not cover all provinces in China, it was designed to make the data representative of the population.

CHNS interviewers asked girls whether they had ever menstruated, and the girl responded yes or no. Unfortunately, the survey did not collect information on AM from adult women, possibly because menarche is an important indicator for child development. Girls in the following age ranges for varying survey years were asked the question: no question regarding menarche in 1989; under 16 in 1991; 10-15 in 1993, 1997, and 2000; 8-17 in 2004, 2006, 2009, and 2011.

[2] Female respondents provided information on their AM in response to the age at menarche or the year at menarche survey questions. Occasionally, AM was recorded in the year at menarche variable, or *vice versa*. Most respondents provided their ages at menarche in the AM variable. We therefore normalised the mistaken and other responses on the basis of this variable, as follows: (1) year at menarche in the year at menarche response, minus the birth year, (2) AM in the year at menarche response, and (3) year at menarche in the AM response.

Because CHNS is a longitudinal panel survey, the same respondent was asked the same question several times, depending on their age. We used the answer to the question provided by each girl in her last follow-up, assuming it to be the most up-to-date information on her menarche. For example, if a girl answered 'no' to the question in 1991 and 1993, but 'yes' in 1997 and was not subsequently surveyed to answer this question due to survey attrition, we used the last answer for analysis. If we only used the answer in 1991, we would miss out on the information that she had not experienced menarche by 1993, but did by 1997. This method allows us to use information on AM for girls who were not continuously tracked. In addition, the data set provides AM in years and months, and therefore to one decimal point.

Following common practice, we use probit analysis to estimate MAM. Because this model is appropriate for girls who are about to experience menarche, we restrict ages to 8-19. The sample size is 3,159. We group the sample by five birth years; the birth year range of the first cohort is 1975-79, and the range of the last group is 2000-03 (not 2000-04, because no girl born in 2004 was included in the CHNS sample).

Obviously, this paper derived information on AM from two methodologically different surveys; the Rec method for CHARLS and the SQ method for CHNS. As mentioned, both methodologies can be expected to generate consistent results.

4. Results

Table 1 lists MAM for each birth year group from the CHARLS and CHNS data sets. For women in the 1925-29 cohort, MAM was 15.88 years, particularly in rural areas. This is fairly high, but consistent with the regional estimates of the 1930s in Figure 1. For birth years 1925-29 to 1940-44, MAM increased marginally, indicative of difficult living conditions during the periods of civil war and war against the Japanese during the 1920s-1940s, as well during adolescence in the 1950s. Particularly in rural areas MAM increased, while it decreased by half a year in urban areas. The MAM of the 1945-49 cohort spiked in both urban and rural areas, which could be indicative of hardship endured during China's civil war, hyperinflation and 1949 crop failure during the 1945-1949 period, but is more likely related to the severe 1959-1962 famine period that affected this cohort of girls at the time of puberty, delaying maturation. From a peak of 16.25 for the 1945-49 cohort, MAM decreased continuously in both urban and rural areas, to an average of 14.74 for the 1970-74 cohort. This is an average decrease of 0.61 (= (16.25-14.74) / 2.5) year per decade, in line with several of the regional data shown in Figure 1.

[Table 1 about here]

The MAM decreased from 13.69 years for the 1975-79 cohort to 12.12 years for 2000-03. This equates to a rate of 0.63 (= (13.69-12.12) / 2.5) year per decade. The trend is generally downward, but the decrease is not monotonic. Between 1975-79 and 1980-84

MAM increased, particularly in rural areas. The difference between the two values for both birth cohorts is statistically significant. Considering the improvement in per capita food consumption (see below), we would expect a downward trend throughout the concerned period, but this is not the case. We hypothesise that this reflects a survival bias for girls born in rural areas during 1975-79, for two reasons.

First, because average living standards were still low, especially in rural areas and regardless of gender, and only healthy children tended to survive in those conditions. Second, the pronounced preference among families in China for sons implies that family resources may have been distributed against girls, particularly in areas where improvements in living standards were slow to take hold (Song *et al.* 2006; Song 2008; Ren *et al.* 2014). It seems likely that these two powerful forces affected particularly the older cohorts in the surveys, and left only very healthy girls to live long enough to participate in the survey. As healthy girls generally experience menarche early, the MAM of the 1975-79 CHNS cohort may probably be biased downward. If relatively unhealthy girls had survived to a greater degree and had participated in the survey, the overall MAM would have been higher than the estimated MAM, because they would have experienced menarche later and would consequently have raised MAM.

It is notable that the average decrease in MAM was the same from 1944-49 to 2000-03. This indicates that the decrease was not necessarily related to the acceleration of GDP per capita growth since 1980, but started well-before that moment. It also indicates that GDP per capita is an imperfect indicator of changes in living standards, at least in the case of post-war China.

Figure 2 shows all MAM estimates and time series from different national surveys that have been conducted in China, and compares them with our estimates. In broad terms, the series reveal similar trends since the mid-1920s: stagnation until a peak in the late-1940s, followed by a continuous decrease to the early-2000s. There are a few notable differences, which need explaining.

[Figure 2 about here]

First, the levels (not the trend) of the FPCFS are much lower. This is due to the fact that Wang and Murphy (2002) estimated MAM after controlling for education, occupation and region of residence of women in the sample in order to standardise the sample across birth years. While this helps to narrow down explanatory factors, the problem with such an adjustment is that it makes comparison with results from other samples difficult.

Second, Figure 2 includes SQ-based estimates of MAM from the often-used quinquennial NSCHS in the form of approximated average birth years (survey year less MAM). The results for survey years 1979, 1985, 1991 and 1995 are significantly lower than ours. The reason is that NSCHS is based on surveys conducted at schools in China. During 1978-1990, a significant but decreasing proportion of children enrolled at primary schools did

not complete their education. On average, 65% of primary school students would continue to complete junior high school, and only 14% of them completed senior high school (Yearbook 2015: Table 21-8). Consequently, the NSCHS surveyed girls at junior and senior high schools for AM, but did not capture the 35% of girls who had not reached junior and the 86% who had not reached senior high schools. China passed a Law on Nine-Year Compulsory Education in 1986. Although the law came into immediate effect, the wording of the law expressed a government ambition to achieve universal compulsory education, not an immediate requirement. No strict penalties on non-compliance were imposed on parents, and it took until 2011 for 9-year compulsory universal education to be achieved (Xie and Mo 2014: 2-3). As there is generally a negative correlation between educational attainment and AM, the NSCHS results have long been biased against girls with higher AM, and MAM is too low.

Third, the differences with CKBB results (Lewington *et al.* 2014) are most likely caused by the fact that those are annual averages, while our estimates are quinquennial averages represented in Figure 2 by the mid-year. Other differences are relatively minor and most likely due to differences in sample sizes, as well as sample biases in terms of urban/rural balance, regions and socio-economic groups represented in each sample.

The spikes in MAM for women born during the late-1940s in the CKBB and CHARLS results in Figure 2 confirm the results for Shanghai city and Beijing in Figure 1. As mentioned, this is possibly related to the hardship caused by the civil war during the late-1940s, but more likely related to the severe 1959-1962 famine period. This famine came at a time when the 1945-49 birth cohort was due to experience menarche. Nutritional deficits at this crucial moment in life may have delayed the release of relevant hormones and the onset of menarche. The subsequent recovery and further decrease of MAM for women born since 1950 is reflected in all series in Figure 2, and also in the longitudinal local studies and the combined results of single year studies in Figure 1. The start and pace of the decreases in Figure 1 may have differed, reflecting regional differences in the moments when living standards started to improve, whether the MAMs reflected urban or rural trends, and possibly any bias in the survey samples. But they clearly suggest that the decrease in MAM preceded the decreases recorded in the CKBB surveys conducted since the 1980s.

The outcomes from the NDRHS (Wu *et al.* 2000) in Figure 2 overlap significantly with our estimates based on CHARLS and CHNS, and the three outcomes combined suggest a continuous decrease from a peak of 16.3 (1947) to 16.5 (1948) in the late-1940s to a low of 12.1 (2002) in the early 2000s, despite the setback in the late-1970s. Altogether a decrease of on average 0.78 years, or just over 9 months per decade. This is almost as fast as in South Korea (Sohn 2017: 6).

Other studies, such as Lin *et al.* (1992) and Ohsawa *et al.* (1997) have on the basis of respectively the 1985 and 1991 NHCHS rounds claimed that the MAM trend in China was downward, but at a decreasing rate. Our results in Figure 2 show no sign of deceleration of MAM. Rather, it accelerates over time if we include the birth cohort 1975-79; alternatively, it

decreases linearly if we exclude this birth cohort. It is of great interest to observe no sign of slow-down in the trend, despite the fact that MAM in China reached 12.1 for the birth cohort 2001-03, which is comparable to the levels of 12.3 and 12.1 years for birth cohorts of the early 1990s recorded in Hong Kong and Taiwan (Chan *et al.* 2009: 20; Lee *et al.* 2017: 316), and similar to the lowest MAM recorded in Western countries where the decreasing trend in MAM did level off (Papadimitriou 2016: 529). The wide confidence interval in Table 1 for the 2001-03 cohort is a warning against hasty conclusions, but it seems that MAM in China may decrease a bit more. Future research will determine whether Chinese girls can reach lower MAM than Western girls as their living standards improve.

5. Improvements in living standards and MAM

The previous section established that the decrease in MAM started well before the acceleration of economic growth after 1980, suggesting that GDP per capita is an imperfect indicator of living standards, at least for China. There is no agreement in the relevant literature as to what factors influence AM, and in what order of significance. Various strands of research have pointed to genetics, prenatal conditions in the mother's uterus, nutritional habits and requirements, nutrition (quantity and quality), reduced disease environment during infancy, childhood and adolescence due to improvements in hygiene and healthcare, exercise and even climate (see *e.g.* Ellis 2004; Karapanou and Papadimitriou 2010). With applications to China, recent studies have established that physical fitness is associated with lower MAM (Fu *et al.* 2013), that birthweight and obesity during childhood and adolescence are negatively correlated with MAM (Yang *et al.* 2017), and that good father-daughter relations and/or stress in the household are negatively correlated with MAM (Weng *et al.* 2013). However, these studies are generally based on small samples. They are difficult to replicate and confirm for larger populations, as the available large data sets generally do not contain the relevant variables.

Studies seeking to explain longitudinal changes in MAM cover similar terrain as studies into long-term changes in infant mortality rates (IMR) or child mortality rates (CMR). For China, Chen (1947: 34-36 and 103-104) found that pre-war IMR was very high and he estimated it at 275 in 1934. This implies a very high CMR of around 350 to 400. Figure 3 confirms that in the 1950s, IMR and CMR had decreased but still very high in China, and that they decreased further from the 1950s to the 1980s.

[Figure 3 about here]

Babiarz *et al.* (2015) studied this decrease and the associated increase in life expectancy at birth from about 35 to 40 years in 1949 to an average of 65.5 years in 1980, noting that this was 'among the most rapid sustained increases in documented global history'. They also analyse explanations for this fast decline in mortality, such as the expansion of primary

healthcare services. Figure 3 shows the availability of hospital beds and medical personnel per person. These are crude indicators, but they confirm that China as a whole is likely to have made significant progress in providing healthcare, despite a set-back in the supply of medical personnel during the early years of the Cultural Revolution after 1966. Other explanations refer to widespread public health campaigns, improvements in water, sanitation, and nutrition, gains in educational attainment.

Babiarz *et al.* (2015) tested these explanations statistically to conclude that the expansion of education during the 1950s together with large-scale public health campaigns jointly explain roughly 50 to 70% of the reduction in China's IMR and CMR. They associated this decrease with the 'lagged, life-long effects of educational gains' in the context of various studies that established better infant and child survival among more educated mothers, and noted that public health interventions complemented gains in general education. Consequently, daughters may not only have benefited from the improved education and increased public health campaigns directed at their mothers since the 1950s during infancy and childhood, in the form of lower IMR and CMR, but possibly also during adolescence in the form of decreasing MAM. Other studies have indicated that access to education and health care continued to improve for later generations of Chinese girls and future mothers (*e.g.* Adams and Hannum 2005).

Nevertheless, Babiarz *et al.* (2015) may have identified only a partial explanation for the decreasing MAM. Their study used regional school enrolment data that are not corrected for actual school attendance. Even when China passed its Law on Nine-Year Compulsory Education in 1986, partial attendance and incomplete completion of primary school and especially junior high school education was still significant. It is likely to have been a bigger issue during the 1950s and 1960s. Consequently, an additional explanatory factor that Babiarz *et al.* (2015) did not account for may be relevant; food supply. This is not a factor that is directly relevant to the mortality of infants and children, as shortfalls in food supply will first of all manifest themselves in stunting and reduced resistance to childhood diseases, rather than mortality. However, shortfalls in food supply would have had a negative impact of growth during infancy and childhood, and the AM of girls.

Figure 4 shows per capita availability of calories per day in China. This indicator takes no account of uneven distributions of food supplies across regions and socio-economic groups. Nevertheless, as a country-level average it has relevance to the nationwide estimates of MAM in Figure 2. Depending on average body size, physical activity, ambient temperature, and the age-sex distribution of the population, average nutritional requirements may have varied over time, but may have been around 1,900 Kcal per day per person, as was the case in Indonesia (Van der Eng 2000: 608-613). Except 1955-1958, average food supplies in China were well below that level until 1973, particularly during the civil war of the late-1940s and the 1959-1962 famine period.[3] In light of son-preference in Chinese families, it

[3] Food production during 1946-1952 was underestimated, as the statistical system to report agricultural production established in 1929 was still under development (Liu and Yeh 1965: 26-32).

seems likely that the biological maturation of girls during those years suffered to a greater degree than boys from the limited food supplies during these years, as the differentials in average heights of birth cohorts for these years confirm (Morgan 2007: Figures 4-10).

[Figure 4 about here]

We use the CHARLS data to test health and nutritional factors that may help to explain trends in MAM in China. Unlike its previous two waves, the CHARLS Wave 3 of 2014 contains information on the socio-economic status during childhood. We used this to determine whether older Chinese women experienced earlier menarche if they benefited from better nutrition, health, and healthcare during childhood. This relationship is well-known across space and time (*e.g.* Ellis 2004; Karapanou and Papadimitriou 2010). It provides a premise to infer the standard of living from MAM. But it is rare to find a study that estimates this relationship for a nationally representative sample of older women on the basis of childhood information, especially in the case of China. For example, Graham *et al.* (1999) regressed AM on individual characteristics, but they collected the sample from two rural counties in Anhui province and relied on current, rather than childhood information.

We included women born between 1930 and 1980 because there were few respondents outside this range. The dependent variable is the answer to the question 'How old were you when you first had a menstrual period?' The respondent selected one of the following five categories: less than 11 years old, between 11 and 12, between 13 and 15, between 16 and 18, and older than 18. We transformed the discrete variable into a continuous one by assigning 10, 11.5, 14, 17 and 19, respectively, to these categories. We regressed this variable on the following independent variables.

We selected independent variables that reflect socio-economic status during childhood. Education is a typical variable because a high level of education indicates that a family could survive without the additional income from a daughter during childhood and adolescence. We also considered self-reported health status before the age of 15 compared to other children of the same age. The respondent chose one of the following five categories: much healthier, somewhat healthier, about average, somewhat less healthy, and much less healthy. Since the proportions of the two extreme categories were small, we combined the first two and the last two categories (we did the same with similarly phrased answers to other questions). We included two proxies for healthcare. One was that whether the respondent had received any vaccinations before 15 years old (yes or no). The other was whether the respondent had always a usual source of medical care such as doctor, nurse, and healthcare centre (yes or no). Since AM decreased over time, we controlled for birth decades.

In addition to education and health, we considered variables that were directly related to the family's socioeconomic status. To measure the experience of dire poverty, we included a variable that asked whether there was a time when the family did not have enough food to eat before the girl was17 years old (yes or no). Besides poverty, we attempted to assess the

family's overall wealth by considering the family's financial situation before the girl's age of 17 years compared to the average family in the same community or village. The respondents chose one of five categories, which we aggregated into three: worse off than them, same as them, and better off than them. Beyond the family environment, the neighbourhood environment can affect AM. We therefore considered the variable that asked whether the neighbourhood of the place where the respondent lived as a child was clean and attractive. The respondent chose one of the following four categories: very clean and attractive, somewhat clean and attractive, not very clean and attractive, and not clean and attractive at all. We dichotomised the variable by aggregating the first two and the last two. Although these variables provided valuable information on the environment during childhood, one needs to be aware that the information was recalled after several decades. Therefore, measurement error is probably large. Nevertheless, given attenuation bias, the coefficients and their statistical significance are conservative.

[Table 2 about here]

The results in Table 2 confirm our expectations, although some coefficients are not statistically significant. Section A confirms the implication of the findings of Babiarz *et al.* (2015) that there is a statistically significant negative correlation between MAM and educational attainment. Roughly, each additional year of education reduced MAM by about one month, so that the completion of senior high school reduced MAM by 1.1 year. As MAM decreased from 16.3 for the 1945-49 cohort to 14.7 for the 1970-74 cohort, improved education explains about 70% (1.1 / (16.3-14.7)) of the decrease of MAM.

Good health during childhood and adolescence made a small but statistically significant contribution to lowering MAM. Both vaccinations and access to health care lowered MAM by a small amount, as expected, but the coefficients were not statistically significant. Selective memory and/or the unavailability of details on the frequency and nature of health interventions during childhood may have limited the statistical significance of this variable. Likewise, food shortage during childhood and adolescence increased MAM somewhat, but the coefficient is not statistically significant. Here, too, selective memory of the details and/or frequency and nature of episodes of shortages of nutrition may have impacted on the results. In addition, the rate at which girls matured may have recovered somewhat after episodes of illness or food shortage due to possible catch-up growth under conditions of improved health and nutrition at a later stage. The memory of growing up in a clean and attractive childhood neighbourhood contributed significantly to lowering MAM, but to a small degree only.

6. Conclusion

This paper offered an overview of the available evidence on long-term changes in the mean age at menarche of women in China, comprising studies of both locally-accumulated and

occasional surveys, as well as analyses of the outcomes of nation-wide and repeated surveys, and covering 120 years, from 1882 to 2002. The broad impression is that MAM was quite high in China until the 1950s; lower in urban areas at a level of about 16 years than in rural areas at a level of around 17 years, possibly higher.

In broad terms, MAM is likely to have decreased in the main urban areas of China before World War II, particularly in Beijing. But that impression may be affected by the fact that many surveys involved girls and women whose families could afford to attend medical facilities in urban areas, at a time when most girls grew up in rural households. More representative national data confirm that MAM for most women born in China in the 1920s and 1930s remained around 16 to 17. Women born in the 1940s experienced an elevated level of MAM to 16.5. This was partially due to the difficult conditions during infancy as a consequence of the war against Japan and the civil war of the 1940s, but most likely due to the drastic food shortages associated with the 1959-1962 famine period that affected these women during adolescence and delayed their AM. For women born after the 1940s, MAM decreased at a consistent and comparatively high rate from 16.5 in the 1940s to 12.1 for girls born in 2002.

The decrease in MAM started well before the acceleration of economic growth and living standards after 1980. Further analysis suggests that especially improved educational opportunities for girls explains most of the decrease of MAM, at least until the early-1970s. It is possible that the expansion and improvement of education facilities during the 1950s and 1960s, in combination with large-scale public health campaigns increased awareness of ways to avoid infant and childhood illnesses that would otherwise have caused death and stunting, and that thus also contributed to decreasing MAM. Macro data suggest that improved medical facilities and food supply must have been a contributing factor, but selective memory among survey participants of the significance of these factors makes it difficult to be conclusive. Since the 1970s, general improvements in living standards in addition to further improvements in education, health and nutrition may have sustained the further decrease of MAM in China.

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Table 1: Mean Age at Menarche in China, CHARLS and CHNS Data Sets, 1925-2003

Birth year cohorts	Total				Urban				Rural			
		95% CI				95% CI				95% CI		
	MAM	lower	upper	N	MAM	lower	upper	N	MAM	lower	upper	N
A. CHARLS												
1925-1929	15.88	15.58	16.19	113	15.75	14.66	16.84	12	15.90	15.58	16.22	101
1930-1934	15.82	15.61	16.04	260	15.48	14.43	16.52	21	15.85	15.64	16.07	239
1935-1939	15.97	15.81	16.13	460	15.26	14.81	15.71	58	16.07	15.90	16.25	402
1940-1944	15.96	15.81	16.11	685	15.21	14.72	15.70	76	16.05	15.90	16.21	609
1945-1949	16.25	16.14	16.37	1,009	15.58	15.21	15.95	114	16.34	16.22	16.46	895
1950-1954	15.93	15.84	16.02	1,615	15.38	15.09	15.66	184	16.01	15.91	16.10	1,431
1955-1959	15.71	15.62	15.81	1,423	15.14	14.87	15.41	181	15.80	15.69	15.90	1,242
1960-1964	15.65	15.56	15.74	1,689	15.03	14.79	15.27	220	15.74	15.65	15.84	1,469
1965-1969	15.23	15.13	15.33	1,177	14.46	14.15	14.77	112	15.31	15.20	15.42	1,065
1970-1974	14.74	14.45	15.02	148	13.31	12.52	14.11	16	14.91	14.62	15.20	132
All				8,579				994				7,585
B. CHNS												
1975-1979	13.69	13.42	13.96	468	13.76	13.30	14.22	117	13.66	13.33	14.00	351
1980-1984	14.30	14.04	14.56	664	13.75	13.33	14.18	186	14.50	14.18	14.83	478
1985-1989	13.52	13.32	13.71	747	13.50	13.13	13.87	220	13.52	13.29	13.75	527
1990-1994	13.01	12.72	13.30	516	12.90	12.34	13.47	160	13.04	12.69	13.38	356
1995-1999	12.77	12.54	13.00	456	12.43	11.91	12.95	160	12.88	12.62	13.14	296
2000-2003	12.12	11.55	12.69	307	11.69	11.31	12.07	114	12.67	11.35	13.99	193
All				3,158				957				2,201

Notes: MAM = mean age at menarche, CI = confidence interval. CHARLS result for 1975-1979 is not included, due to low number of observations (26, MAM = 14.85).
Sources: Calculated from data of the China Health and Retirement Longitudinal Study (CHARLS) http://charls.pku.edu.cn/en and the China Health and Nutrition Survey (CHNS) http://www.cpc.unc.edu/projects/china.

Table 2: Analysis of Age at Menarche and Childhood Background, 1930-1979

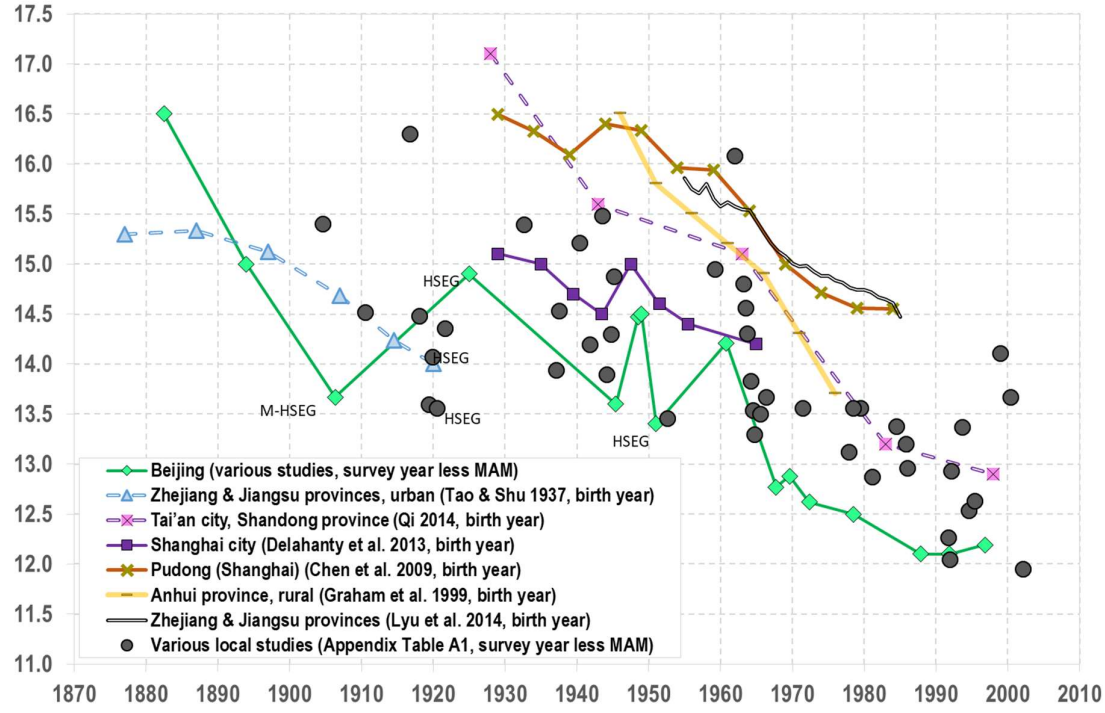
Independent variables	Coefficient
A. Education	
Less than primary education	reference
Primary education	-0.46 (0.05)*
Junior high school	-0.75 (0.06)*
Senior high school or above	-1.11 (0.08)*
B. Health and healthcare	
Health status before 15 (compared to other children of same age)	
Less healthy	reference
About average	-0.20 (0.06)*
Healthier	-0.20 (0.07)*
Did the respondent received any vaccinations before 15?	
No	reference
Yes	-0.02 (0.06)
Had the respondent a usual source of care (*e.g.* doctor, nurse, or healthcare centre) when sick?	
No	reference
Yes	-0.11 (0.07)
C. Food and living environment	
Was there a time when the family did not have enough food to eat before age 17?	
No	reference
Yes	0.09 (0.05)
Compared to the average family in the same community/village, the family's financial situation before 17?	
Worse off than them	reference
Same as them	0.03 (0.05)
Better off than them	-0.09 (0.07)
Was the childhood neighbourhood clean and attractive?	
No	reference
Yes	-0.12 (0.04)*
D. Birth decade	
1930-1939	reference
1940-1949	0.47 (0.10)*
1950-1959	-0.06 (0.09)
1960-1969	-0.42 (0.10)*
1970-1979	-1.11 (0.11)*
N	9,529
Adjusted R-squared	0.094

* = p-value < 0.05.

Notes: OLS Dependent variable: recalled age at menarche. Continuous age at menarche was created from five categories as follows: if less than 11 years old, 10 years; if between 11 and 12 years old, 11.5 years; if between 13 and 15 years old, 14 years; if between 16 and 18 years old, 17 years; and if older than 18, 19 years. Birth years restricted to 1930-1979.

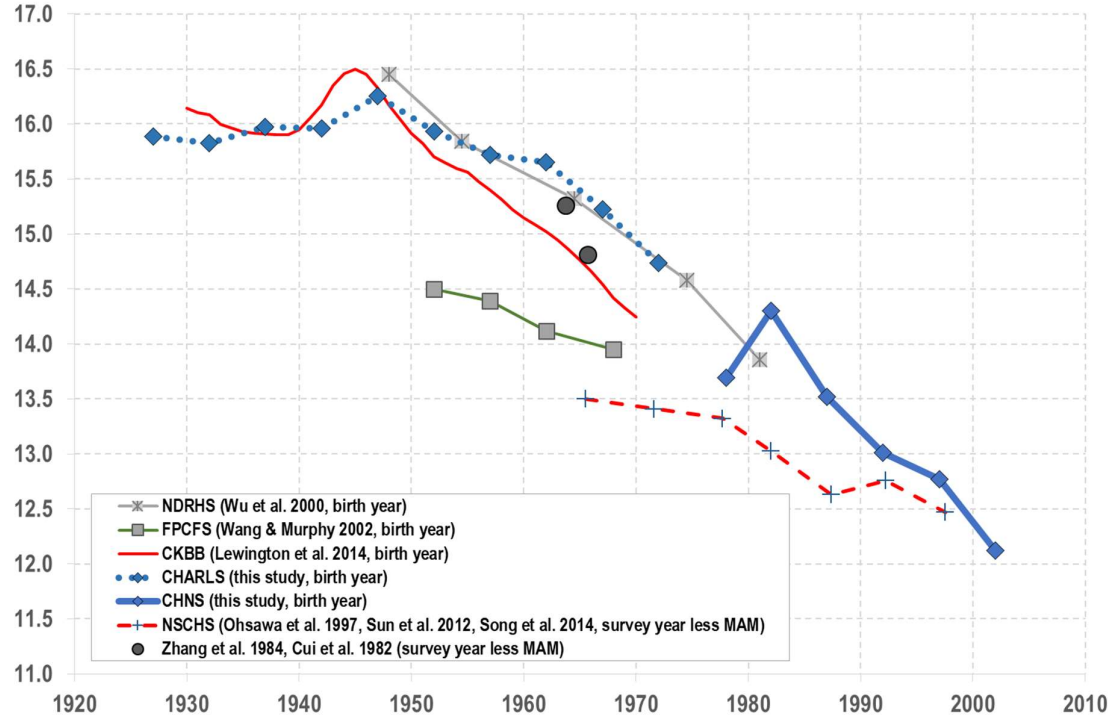
Source: Calculated from China Health and Retirement Longitudinal Study (CHARLS).

Figure 1: Mean Age at Menarche from Regional Surveys in China, 1877-2002



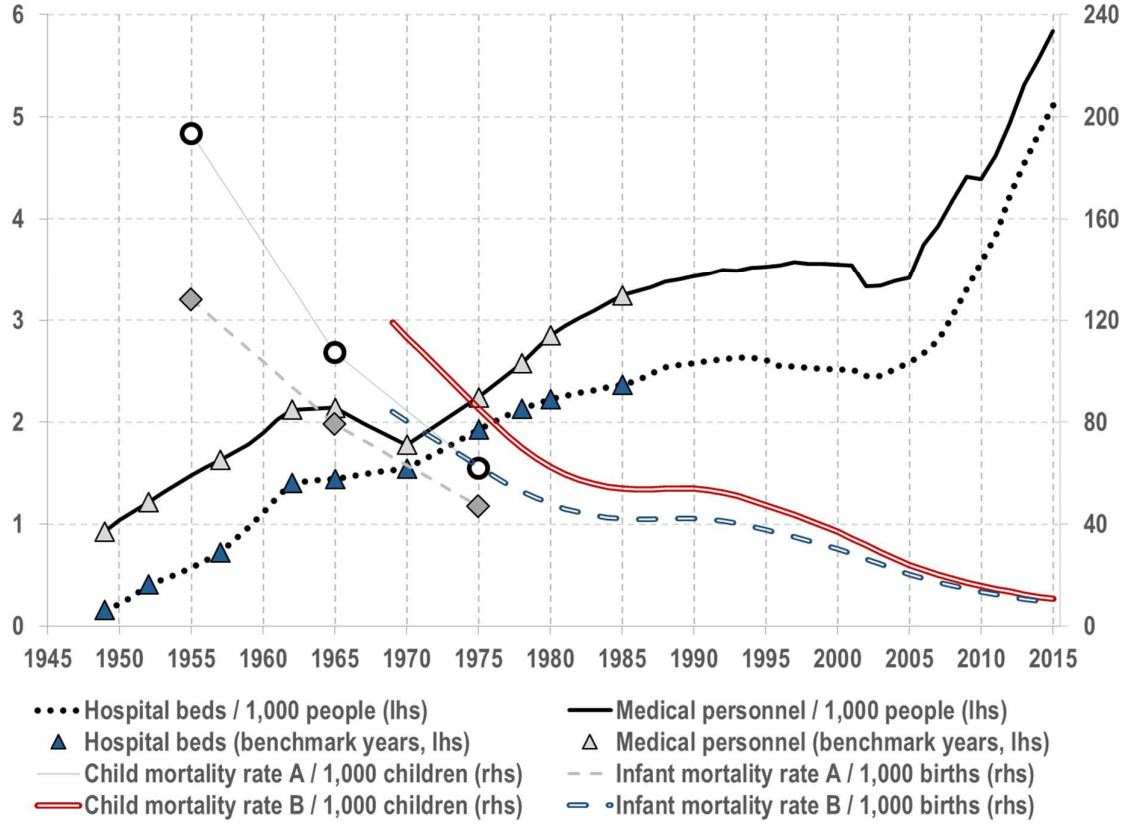
Note: By average birth year or simulated birth year (*i.e.* survey year less MAM). MAM = mean age at menarche. M-HSEG = medium to high level socio-economic group. HSEG = high level socio-economic group.
Sources: As indicated, and Appendix Table A1.

Figure 2: Mean Age at Menarche from National Surveys in China, 1925-2003



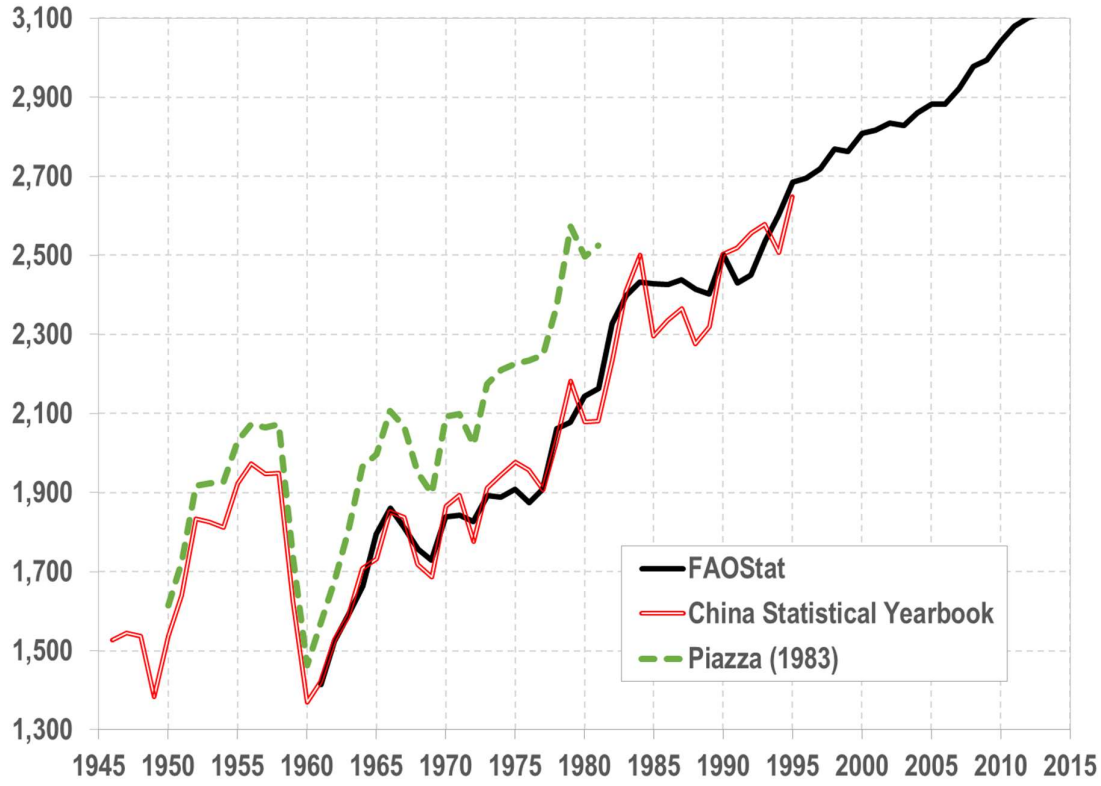
Note: By average birth year or simulated birth year (= survey year less MAM). MAM = mean age at menarche.
Sources: Table 1 and as indicated.

Figure 3: Indicators of Changes in Healthcare in China, 1949-2015



Notes: IMR and CMR 1955, 1965 and 1975 are averages of 1950-59, 1960-69 and 1970-80.
Sources: Hospital beds and medical personnel 1949-2015 Yearbook (various years); IMR A and CMR A Babiarz *et al.* (2015) 45; IMR B and CMR B World Bank http://data.worldbank.org/

Figure 4: Per Capita Food Supply in China, 1946-2013 (Kcal per day)



Notes: 1946-1995 is per capita staple grains production, linked for 1961-1976 to per capita Kcal supply from FAOStat. Piazza (1983) used different calorie conversion rates and population data than the FAO.
Sources: ECAFE (1947-1951); State Statistical Bureau (1974) and Yearbook (1980-2000); FAOStat http://www.fao.org/faostat/en/; Piazza (1983).

Appendix Table A1: Age at Menarche of Women in China and of Ethnic Chinese Women in Other Countries, Results from Studies

Province, sub-group	Survey year	Sample size	Method	Ages or birth years	Mean or median	Source (original and = used source)
Beijing	<1899	50	Rec		16.50	Matignon (1899) p.11, also in Edwards (1982) p.8
Beijing, approximation	<1909	220	SQ		15.00	Gaupp (1909) p.733, also in Edwards (1982) p.8
Fujian province, Yongchun town	<1920	599	?		15.40	Preston Maxwell (unpublished) in Mills (1937) p.46
Beijing, 'middle-upper class' M-HSEG	1917-25	1,590	Rec	aged 20<	13.67	Heath (1925) p.702, also in Edwards (1982) p.6
Guangzhou, urban	<1925	869	Rec	aged 9-26	14.09	Chau and Wright (1925) p.683, also in Edwards (1982) p.6
Guangdong, rural	<1925	1,422	Rec	aged 9-26	14.78	Chau and Wright (1925) p.683, also in Edwards (1982) p.6
Guangdong, total sample	<1925	2,291	Rec	aged 9-26	14.52	Chau and Wright (1925) p.683, also in Edwards (1982) p.6
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	92	Rec	aged 10-15	14.00	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai urban	1931-34	331	Rec	aged 16-20	14.24	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	398	Rec	aged 21-30	14.68	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	249	Rec	aged 31-40	15.12	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	103	Rec	aged 41-50	15.33	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	20	Rec	aged 51-60	15.30	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban	1931-34	8	Rec	aged 61-70	14.88	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Zhejiang and Jiangsu provinces, and Shanghai, urban, total	1931-34	1,201	Rec	aged 10-70	14.48	Calculated from Tao and Shu (1937) p.300 (age adjusted)
Shanghai, Wuxi and Ningbo, urban, students, HSEG	1933	339	?		13.60	Tao *et al.* (1936) in Tao and Shu (1937) p.298 (age adjusted)
Shanghai, Wuxi and Ningbo, urban, non-students	1933		?		16.30	Tao *et al.* (1936) in Tao and Shu (1937) p.298 (age adjusted)
Shanghai and Wuchong cities, middle school/college, HSEG	<1934	309	Rec		13.56	Westbrook *et al.* (1934) p.42
Shanghai, Nanjing, Suzhou, urban, HSEG	<1934	2,924	Rec	80%+ <25y	14.07	Yang and Gear (1934) p.645
Hunan province, Changsha city, middle schools	<1936	2,000	Rec		14.36	Calculated from Chang (1936) p.974 (age adjusted), also in Edwards (1982) pp.3 and 6
Beijing, HSEG	1948-54	3,608	Rec	1918-1932	14.90	Chen, Wang and Mi (2014) p.76
Shanghai	1947-49	857	Rec	aged 15-30	15.39	Yu (1951) p.147 (age adjusted)
Dalian, students from Central China	<1953	436	Rec		14.19	Xiong (1953) p.233
Dalian, students from Northern China	<1953	486	Rec		14.84	Xiong (1953) p.233
Dalian, total	<1953	922	Rec	aged 15-35	14.53	Calculated from Xiong (1953) p.233

Shanghai	1955	510	Rec	aged 10-18	13.94	Zhao (1957) p.355
Guangzhou, urban	<1957	1,887	Rec	aged 15-90	14.20	He and Lin (1957) p.351 (age adjusted), also in Edwards (1982) p.10
Henan province, Zhengzhou city	1958	517	Rec	aged 9-16	13.90	Zhang and Wang (1963) p.258
Hubei province, Wuhan city, urban	1959	15,023	Rec	aged 14-90	14.61	Wuhan School of Medicine (1960) p.10 (age adjusted)
Hubei province,Yingcheng county, rural	1959	5,947	Rec	aged 14-90	15.54	Wuhan School of Medicine (1960) p.10 (age adjusted)
Hubei province, total	1959	20,970	Rec	aged 14-90	14.87	Calculated from Wuhan School of Medicine (1960) p.10 (age adjusted, Edwards (1982) p.10)
Beijing	<1960	543	?		13.60	Luo (1960) in Zhongshan Medical College (1982) p.790
Guangxi province, Baise county, rural	<1960	413	Rec	aged 13-24	14.30	Yan (1960) p.14
Hubei province, Wuhan city, rural suburb	1959	410	Rec	aged 12-26	15.48	Yang (1960) p.11
Beijing	1963	933	?		14.47	Beijing Normal University (1977) p.97
Beijing, HSEG	1960s	479	Rec	1948-1954	13.40	Chen, Wang and Mi (2014) p.76
Beijing, average economic status	1963-64	1,667	Rec		14.50	Ye *et al.* (1981) pp.102-103
Beijing, Yangzhuang district	1975	735	SQ		14.27	Beijing Normal University (1977) p.97 (age adjusted)
Beijing, Shunyi district	1975	438	SQ		14.11	Beijing Normal University (1977) p.99 (age adjusted)
Beijing, total	1975	1,173	SQ		14.21	Calculated from Beijing Normal University (1977) pp.97 and 99
Shandong province, Yantai city	<1978	55,140	?		14.80	Unpublished study in Zhongshan Medical College (1982) p.790
Liaoning province, Liaoning city	<1978	8,379	?		14.56	Unpublished study in Zhongshan Medical College (1982) p.790
Guangdong province, Zhaoqing city	<1978	1,238	?		13.30	Unpublished study in Zhongshan Medical College (1982) p.790
Harbin	<1978	3,714	?		13.83	Unpublished study in Zhongshan Medical College (1982) p.790
Henan province, Zhengzhou city	<1978	2,097	?		13.54	Unpublished study in Zhongshan Medical College (1982) p.790
Jilin province, Jilin county, Hailong town	<1978	2,051	?		16.08	Unpublished study in Zhongshan Medical College (1982) p.790
Guangxi province, Zhuang Autonomous Region	<1978	3,967	?		14.31	Unpublished study in Zhongshan Medical College (1982) p.790
Shanghai	1978-79	2,202	SQ	aged 7-18	14.10	Zhang *et al.* (1982) p.166
National	1978-80	131,410	Rec	aged 9-20	15.26	Zhang *et al.* (1984) p.192 (age adjusted)
National	1979	?	SQ		13.50	Sun *et al.* (2012) p.283
Dalian	1980	1,601	SQ		13.56	Jiang (1981) in Cui *et al.* (1986) p.1-2
Beijing, Haidian district	1979-86	973	?		12.88	Li (1988) in Liu (1997) p.308
Nanjing	1980	1,660	SQ		13.67	Li *et al.* (1981) p.351
Beijing, total	1980-81	2,343	Rec		14.14	Cui *et al.* (1982) pp.488-489
Beijing, urban	1980-81	820	SQ	aged 10-25	12.77	Cui *et al.* (1982) pp.488-489

Beijing total	1980-81	1,805	SQ	aged 10-25	13.94	Cui *et al.* (1982) pp.488-489
National, urban	1980-81	2,756	Rec		13.57	Cui *et al.* (1982) pp.488-489
National, rural	1980-81	8,629	Rec		15.23	Cui *et al.* (1982) pp.488-489
National, total	1980-81	11,385	Rec		14.83	Cui *et al.* (1982) pp.488-489
National, urban	1980-81	1,663	SQ		12.79	Cui *et al.* (1982) pp.488-489
National, rural	1980-81	9,932	SQ		15.15	Cui *et al.* (1982) pp.488-489
National, total	1980-81	11,595	SQ		14.81	Cui *et al.* (1982) pp.488-489
Guangdong province, Guangzhou and Foshan	<1982	2,134	Rec		12.95	Zhongshan Medical College (1982) pp.790 and 795
Guangdong province, Wengyan and Yangshan rural counties	<1982	341	Rec		13.72	Zhongshan Medical College (1982) pp.790 and 795
Guangdong province, Taishan coastal county	<1982	906	Rec		13.89	Zhongshan Medical College (1982) pp.790 and 795
Guangdong province, total	<1982	3,381	Rec	aged 9-18	13.26	Zhongshan Medical College (1982) pp.790 and 795
Shanghai, medical college	1984-87	1,237	Rec	1961-1971	13.46	Calculated from Liu *et al.* (1989) p.17
Beijing	1985	4,248	SQ		12.62	Lin *et al.* (1992) p.508
National, urban, Han women	1985	84,652	SQ		13.17	Lin *et al.* (1992) p.508
National, rural, Han women	1985	78,250	SQ		13.80	Lin *et al.* (1992) p.508
National, other women	1985	34,232	SQ		14.00	Lin *et al.* (1992) p.508
National, total	1985	197,134	SQ		13.56	Calculated from Lin *et al.* (1992) p.508
Beijing	1985	2,446	SQ	aged 9-20	12.62	Chen, Wang and Mi (2014) p.76 and Lin *et al.* (1992) p.510
National, urban, Han women	1985	61,487	SQ		13.09	Song *et al.* (2014) pp.1173 and 1178
National, rural, Han women	1985	61,416	SQ		13.73	Song *et al.* (2014) pp.1173 and 1178
National, total, Han women	1985	122,903	SQ		13.41	Song *et al.* (2014) pp.1173 and 1178
National	1988	7,418	Rec	1950-1954	14.50	Wang and Murphy (2002) p.357
National	1988	7,702	Rec	1955-1959	14.39	Wang and Murphy (2002) p.357
National	1988	8,199	Rec	1960-1964	14.12	Wang and Murphy (2002) p.357
National	1988	4,336	Rec	1965+	13.95	Wang and Murphy (2002) p.357
Shanghai	1989	536	Rec	1972-1978	12.91	Wang *et al.* (1991) p.4
Urban, various provinces	1989	1,500	Rec	aged 11-20	13.38	Yang (2001) p.138
National, urban, Han women	1991	32,176	SQ		13.01	Ohsawa *et al.* (1997) p.207
National, rural, Han women	1991	32,146	SQ		13.64	Ohsawa *et al.* (1997) p.207
National, total, Han women	1991	64,322	SQ		13.32	Ohsawa *et al.* (1997) p.207
Beijing	1991	1,016	SQ	aged 9-18	12.50	Chen, Wang and Mi (2014) p.76; Ohsawa *et al.* (1997) p.207

Guangxi province, Zhuang nationality, urban	1991	?	SQ	aged 7-22	12.97	Wang (1994) p.55
Guangxi province, Zhuang nationality, rural	1991	?	SQ	aged 7-22	13.12	Wang (1994) p.55
China, 22 cities	1991-92	8,069	SQ	aged 12-18	13.08	Weighted average calculated from Hu *et al.* (1995) p.2
Weifang city	1993-94	282	SQ	aged 10-16	13.56	Liu (1997) p.307
Zhejiang and Jiangsu provinces	1991-96	7,128	Rec	1955-1960	15.70	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces	1993-97	53,245	Rec	1961-1965	15.50	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces	1995-97	309,379	Rec	1966-1970	15.10	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces	1996-00	369,971	Rec	1971-1975	14.90	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces	2000-04	348,356	Rec	1976-1980	14.80	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces	2003-08	79,040	Rec	1981-1985	14.70	Lyu *et al.* (2014) p.3
Zhejiang and Jiangsu provinces, total	1991-08	1,167,119	Rec	1955-1985	14.94	Calculated from Lyu *et al.* (2014) p.3
Anhui province, two rural counties	1993	3,894	Rec	<1949	16.50	Graham *et al.* (1999)
Anhui province, two rural counties	1993	1,228	Rec	1949-53	15.80	Graham *et al.* (1999)
Anhui province, two rural counties	1993	1,422	Rec	1954-58	15.50	Graham *et al.* (1999)
Anhui province, two rural counties	1993	1,442	Rec	1959-63	15.20	Graham *et al.* (1999)
Anhui province, two rural counties	1993	2,050	Rec	1964-68	14.90	Graham *et al.* (1999)
Anhui province, two rural counties	1993	1,492	Rec	1969-73	14.30	Graham *et al.* (1999)
Anhui province, two rural counties	1993	1,198	Rec	1974-78	13.70	Graham *et al.* (1999)
Seven cities, railway middle schools	1994	2,449	Rec		12.87	Unweighted average from Zhang *et al.* (2000) p.16
National, urban, Han women	1995	43,669	SQ		12.82	Song *et al.* (2014) pp.1173 and 1178
National, rural, Han women	1995	41,760	SQ		13.26	Song *et al.* (2014) pp.1173 and 1178
National, total, Han women	1995	85,429	SQ		13.03	Song *et al.* (2014) pp.1173 and 1178
National	1997	769	Rec	1947-49	16.45	Wu *et al.* (2000) p.89
National	1997	3,904	Rec	1950-59	15.84	Wu *et al.* (2000) p.89
National	1997	4,987	Rec	1960-69	15.32	Wu *et al.* (2000) p.89
National	1997	4,116	Rec	1970-79	14.58	Wu *et al.* (2000) p.89
National	1997	903	Rec	1980-82	13.86	Wu *et al.* (2000) p.89
National	1997	14,679	Rec	1947-82	15.22	Wu *et al.* (2000) p.89
Urban (Shanghai, Beijing, Guangzhou, Wuhan)	1999	1,500	Rec	aged 11-20	12.54	Yang (2001) p.138
Zhejiang province, Hangzhou city, urban	1999	1,171	SQ	aged 13-16	12.80	Hesketh *et al.* (2002) p.349
Zhejiang province, Chunan district, rural	1999	815	SQ	aged 13-16	13.20	Hesketh *et al.* (2002) p.349

Zhejiang province, total sample	1999	1,986	SQ	aged 13-16	12.96	Hesketh *et al.* (2002) p.349
National	2000	?	SQ		12.63	Sun *et al.* (2012) p.283
Beijing	2000	1,402	SQ	aged 9-18	12.10	Chen, Wang and Mi (2014) p.76
Shanghai	2000	31,955	Rec	av.1940	15.21	Wu *et al.* (2014) p.3
Nanjing, urban	1999	9,811	SQ	aged 9-18	12.98	Lin *et al.* (2002) p.226
Nanjing, rural	1999	3,683	SQ	aged 9-18	13.76	Lin *et al.* (2002) p.226
Nanjing, total	1999	13,494	SQ	aged 9-18	13.20	Lin *et al.* (2002) p.226
Tai'an city, Shandong province	<2014	1,974	Rec	aged 80+	17.10	Qi (2014) p.134
Tai'an city, Shandong province	<2014	2,001	Rec	aged 60-79	15.60	Qi (2014) p.134
Tai'an city, Shandong province	<2014	2,005	Rec	aged 40-59	15.10	Qi (2014) p.134
Tai'an city, Shandong province	<2014	2,009	Rec	aged 20-39	13.20	Qi (2014) p.134
Tai'an city, Shandong province	<2014	2,011	Rec	aged <20	12.90	Qi (2014) p.134
Shanghai	2000s	6,929	Rec	1926-1985	14.63	Calculated from Delahanty *et al.* (2013) p.1137
National	2004-08	300,586	Rec	1925-1978	15.40	Lewington *et al.* (2014) pp.1255-1256
National, 9 cities, urban	2003-05	20,654	SQ	aged 3-20	12.27	Ma *et al.* (2009) = Mao *et al.* (2011) p.136
Beijing, urban	2004	4,959	SQ		11.90	Chen, Wang and Mi (2014) p.76
Beijing, rural	2004	4,731	SQ		12.50	Chen, Wang and Mi (2014) p.76
Beijing, total	2004	9,778	SQ		12.10	Chen, Wang and Mi (2014) p.76
Anhui province	2004-05	9,097	Rec	25-64, av.44.8	14.95	Feng *et al.* (2009) p.593
Nanning city, Guangxi autonomous area	<2005	5,767	SQ	aged 3-16	12.05	Chen *et al.* (2005) p.163
National, urban, Han women	2005	47,737	SQ		12.60	Song *et al.* (2014) pp.1173 and 1178
National, rural, Han women	2005	45,030	SQ		12.92	Song *et al.* (2014) pp.1173 and 1178
National, total, Han women	2005	92,767	SQ		12.76	Song *et al.* (2014) pp.1173 and 1178
National	2005	?	SQ		12.17	Sun *et al.* (2012) p.283
Anhui province (Huangshan, Hefei, Suzhou), urban	2005	1,500	SQ	aged 9-18	12.76	Wang *et al.* (2007) abstract & text
Anhui province (Huangshan, Hefei, Suzhou), rural	2005	1,500	SQ	aged 9-18	13.11	Wang *et al.* (2007) abstract & text
Anhui province (Huangshan, Hefei, Suzhou), total	2005	3,000	SQ	aged 9-18	12.94	Calculated from Wang *et al.* (2007) abstract & text
Shaanxi province	2007	42	Rec	before 1968	15.35	Wang (2016) p.2 and 6
Shaanxi province	2007	600	Rec	1968-1988	14.55	Wang (2016) p.2 and 6
Shaanxi province	2007	600	Rec	after 1988	13.37	Wang (2016) p.2 and 6
Shaanxi province, total	2007	1,242	Rec		14.01	Calculated from Wang *et al.* (2016) p.2 and 6

Sichuan province	<2007	446	SQ		13.33	Liu *et al*. (2007) p.1278
Pudong (Shanghai)	2007-08	56,933	Rec	aged 25-75	15.71	Calculated from Chen *et al*. (2009) p.501
Changzhou province, urban and rural	2008	13,047	SQ		12.63	Mao *et al*. (2011) p.136
Beijing	2009	6,156	SQ	aged 6-19	12.19	Guo and Ji (2011) p.453
National, urban, Han women	2010	42,786	SQ		12.35	Song *et al.* (2014) pp.1173 and 1178
National, rural, Han women	2010	42,727	SQ		12.59	Song *et al.* (2014) pp.1173 and 1178
National, total, Han women	2010	85,513	SQ		12.47	Song *et al.* (2014) pp.1173 and 1178
National, 8 provinces, urban and rural	2010-11	15,388	SQ		12.43	Sun *et al.* (2012) p.282
Wuhan	<2013	338	Rec		12.30	Weng (2013) p.1210
Shaanxi province, vocational high school	<2014	590	Rec	av. ca.17	14.11	Jia and Yu (2014) abstract
Anhui province (Hefei, Chizhou, Suzhou), urban	2014	?	SQ	aged 7-18	11.68	Wang *et al.* (2016) p.332
Anhui province (Hefei, Chizhou, Suzhou), rural	2014	?	SQ	aged 7-18	12.21	Wang *et al.* (2016) p.332
Anhui province (Hefei, Chizhou, Suzhou), total	2014	4,844	SQ	aged 7-18	11.95	Wang *et al.* (2016) p.332
Shaanxi province, urban	2014-15	2,236	SQ		12.85	Chen *et al.* (2016) abstract
Shaanxi province, rural	2014-15	4,119	SQ		13.69	Chen *et al.* (2016) abstract
Shaanxi province, total	2014-15	6,355	SQ		13.67	Chen *et al.* (2016) abstract
Hong Kong						
Hong Kong Chinese	1935	464	?		15.21	Mills (1935) in Mills (1937) p.46
South China origin, HSEG	1961-62	855	SQ	aged 6-20	12.51	Lee *et al*. (1963) p.391
South China origin, MSEG	1961-62	1,047	SQ	aged 6-20	12.75	Lee *et al*. (1963) p.391
South China origin, LSEG	1961-62	1,376	SQ	aged 6-20	13.25	Lee *et al*. (1963) p.391
South China origin, average	1961-62	3,278	SQ	aged 6-20	12.85	Lee *et al*. (1963) p.391
Chinese, HSEO	1961-63	1,528	SQ		12.63	Low *et al*. (1982) p.544
Chinese, LSEO	1961-63	1,097	SQ		13.25	Low *et al*. (1982) p.544
Chinese, HSEO	1977-79	273	SQ		12.41	Low *et al*. (1982) p.544
Chinese, LSEO	1977-79	991	SQ		12.65	Low *et al*. (1982) p.544
Hong Kong Chinese	1977-79	1,264	SQ		12.59	Low *et al*. (1982) p.544 in Huen *et al*. (1997) p.1123
Hong Kong Chinese	1986-87	123	Rec	aged 11-12	11.50	So and Yen (1992)
Hong Kong Chinese, HSEG	1993	1,487	SQ	aged 8-18	12.42	Leung *et al.* (1996) p.304
Hong Kong Chinese, MSEG	1993	3,522	SQ	aged 8-18	12.39	Leung *et al.* (1996) p.304

Hong Kong Chinese, LSEG	1993	1,611	SQ	aged 8-18	12.37	Leung *et al.* (1996) p.304
Hong Kong Chinese average	1993	6,620	SQ	aged 8-18	12.39	Calculated from Leung *et al.* (1996) p.304
Hong Kong Chinese	1993	6,467	SQ		12.38	Huen *et al.* (1997) p.1123
Hong Kong Chinese	1995-2000	1,080	Rec	av.47.5	13.70	Cheung *et al.* (2014) p.50
Hong Kong Chinese	<2003	1,573	?	aged 8-15	11.67	Tang *et al.* (2003) p.196
Hong Kong	2005-06	5,609	Rec	1993.2	12.30	Chan *et al.* (2009) p.20
Hong Kong Chinese	2001-10	631	Rec	av.47.3	13.00	Cheung *et al.* (2014) p.50
Taiwan						
South-west	<1909	135	Rec	aged 11-22	16.65	Yamasaki (1909) p.1302-1303
North	<1909	100	Rec		16.18	Yamasaki (1909) p.1303
?	<1933	?	?	<20	14.17	Ko (1933) in Edwards (1982) p.7
Taipei, Hsinchuang industrial township	1970	3,616	Rec		14.60	Ko *et al.* (1985) p.120
Taipei, Kungliau fishing township	1970	2,091	Rec		15.40	Ko *et al.* (1985) p.120
Taipei, total	1970	5,707	Rec		14.87	Ko *et al.* (1985) p.120
?	1994	?	Rec		13.60	Chow *et al.* (1997) abstract
Taichung city	1999	195	Rec	av.1926	15.16	Chang and Chen (2008) p.397-398
Taichung city	1999	200	Rec	av.1953	14.50	Chang and Chen (2008) p.397-398
Taichung city	1999	200	Rec	av.1978	13.00	Chang and Chen (2008) p.397-398
Taichung, urban	<2012	48	Rec	aged 9-14	11.67	Liu *et al.* (2012) p.44
North, urban	2000-07	1,545	Rec	1991.4	12.11	Lee *et al.* (2016) p.3
USA						
Los Angeles, ethnic Chinese college students	1940	17	Rec		13.94	Ito (1942) p.339
Hawaii, ethnic Chinese	1974-75	395	Rec	1900-1940	13.00	Goodman *et al.* (1983) p.51
USA and Canada, girls adopted from China	2005-11	814	Rec		12.37	Hayes and Tan (2016) p.255
Malaysia						
University students, ethnic Chinese	2010-11	120	Rec	aged 18-25	12.55	Hossein *et al.* (2013) p.709
Singapore						
Higher social levels	1953	58	Rec		13.60	Wadsworth (1953) p.111
University students	1952-54	415	Rec		13.10	Aw and Tye (1970) p.333
University students	1964-66	896	Rec		12.70	Aw and Tye (1970) p.333

Wealthy	1968	895	Rec		12.40	Aw and Tye (1970) p.332
Average	1968	627	Rec		12.66	Aw and Tye (1970) p.332
Poor	1968	806	Rec		12.98	Aw and Tye (1970) p.332
Total sample	1968	2,238	Rec		12.69	Aw and Tye (1970) p.332
Singapore Chinese	1987	193	SQ	aged 7-19	12.88	Calculated from Loke *et al.* (1991) p.131
Singapore Chinese	<1992	614	Rec	aged 40-70	13.91	Calculated from Lee *et al.* (1992) pp.315-316
Singapore Chinese	1993-98	671	Rec	1917-1953	14.41	Calculated from Wu *et al.* (2003) p.453
Singapore	2003	3,235	SQ	aged 9-13	11.50	Yong *et al.* (2009) p.1058
Singapore (77% ethnic Chinese in sample)	2004	5,238	Rec	aged 9-16	12.15	Agarwal and Venkat (2009) p.366
Singapore Chinese	1993-98	31,058	Rec	av.1938.7	14.40	Mueller *et al.* (2012) p.719
Indonesia						
Surabaya (Java), urban	1959	2,707	SQ	aged 8-21+	13.55	The and Soepatmi (1962) p.347
Indochina						
Cholon, Cochinchina, South Vietnam, urban	1874	106	Rec		16.50	Mondiere (1882) p.489; Mondiere (1880) p.258

a. 13th or 14th year of life, i.e. ages of 12-13.

HSEG = Higher Socio-Economic Group

MSEG = Middle Socio-Economic Group

LSEG = Lower Socio-Economic Group

Methodology: SQ = status quo, generally median with probit or logit; Rec = recollection, generally mean.

All ages in terms of last birthday, *e.g.* 13.1 is the 14th year of life. In some cases Chinese system of recording age adjusted by 0.5 years