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Health, Height, Height Shrinkage and SES at Older Ages: Evidence from China[*†]

Wei Huang[‡] Xiaoyan Lei[§] Geert Ridder[**] John Strauss[††] Yaohui Zhao[‡‡]

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Abstract

Adult height, as a marker of childhood health, has recently become a focus in understanding the relationship between childhood health and health outcomes at older ages. However, measured height of the older individuals is contaminated by height shrinkage from aging. Height shrinkage, in turn may be correlated with health conditions and socio-economic status from throughout the life-cycle. In this case it would be problematic to use measured height directly in regressions without considering such an effect. In this paper, we tackle this problem by using upper arm

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[†] This research is supported by National Institute of Aging, the Natural Science Foundation of China, Fogarty International Center, the World Bank, and the Peking University-Morgan Stanley Scholarship.

[‡] Harvard University

[§] Peking University and IZA

[**] University of Southern California

[††] University of Southern California

[‡‡] Peking University and IZA

length and lower leg length to estimate a pre-shrinkage height function for a younger population that should not have started their shrinkage. We then use these estimated coefficients to predict pre-shrinkage heights for an older population, for which we also have upper arm and lower leg lengths. We then estimate height shrinkage for this older population and examine the associations between shrinkage and socio-economic status variables. We provide evidence that height shrinkage for both men and women is negatively associated with better current SES and early life conditions and, for women, positively with pre-shrinkage height. We then investigate the relationships between pre-shrinkage height, height shrinkage and a rich set of health outcomes of older respondents, finding that height shrinkage is positively associated with poor health outcomes across a variety of outcomes, with results for older age cognition being especially strong. Indeed height shrinkage is more strongly associated with later life outcomes than is pre-shrinkage height, suggesting that later life conditions are especially important correlates for these outcomes.

Key words: Height, Height shrinkage, Health, China

JEL classification: D1, I12, J13

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I. Introduction

The rapid aging of population places health at older ages among the top public health priorities in recent years as the fraction of the population that is elderly has been rising. In countries such as China, rapid aging has occurred at much lower levels of national income and worse health conditions than was the case in industrial countries. The elderly in such countries were children when economic development and health conditions were far worse than today and their health as adults is likely to have been affected by such past conditions, more so than the elderly in industrial countries.

The effects of early-life health and environment on cognitive function, health, wellbeing and mortality have been documented by researchers across a range of disciplines, using data from many countries over the world (Elo and Preston, 1992; Barker, 1994; Godfrey and Barker, 2000; Finch and Crimmins, 2004; Case et al., 2005, 2008b, 2010a, b; Alderman and Behrman, 2006; Zeng et al., 2007; Van den Berg, 2006; Smith, 2009; Huang and Elo, 2009, Almond and Currie, 2011).

There are several literatures that have used height to proxy for past health. In the large historical literature, adult height is taken to be an indicator of population health (Fogel, 1986, 2004; Steckel, 1995, 2009). The nutrition literature long ago established that child height is a very good summary measure of overall health of children (e.g. Martorell and Habicht, 1986). Adult height while reflective of the adolescent growth spurt, is also highly correlated with height during childhood.

A strong association has been found to exist among the elderly between measured height and cognitive ability, self-reported health, illness status and measures of depression (Case and Paxson, 2008a; Case and Paxson, 2010a; Deaton and Arora, 2009; Heineck, 2008; Maurer, 2010; Smith et al., 2012). Most of this literature is from industrial countries (Maurer, 2010 and Smith et al., 2012, are exceptions). The exact mechanisms are not completely known, as these studies are not structural, nor causal. Some of the pathway is likely to be through better health during childhood and prime-aged adulthood (e.g. Case and Paxson, 2008b or Smith, 2009), but other pathways exist as well, such as taller people having more schooling and consequently making better health behavior decisions (e.g. Cutler and Lleras-Muney, 2010).

However, older people suffer height shrinkage during aging. Aging is associated with several physiological and biological changes, including body composition, such as an increase in body fat, a decrease in lean body mass and bone mass (Kuchmarsk, 1989). Through such mechanisms as certain kinds of arthritis (such as ankylosing spondylitis), inflammation of spine joints, herniated disks, or kyphosis, these changes can lead to vertebral deformity, which can contribute to a reduction in height (Kwok et al., 2002; Prothro, 1993; Roubenoff and Wilson, 1993). One health condition that can influence shrinkage directly and through many of these other proximate causes is osteoporosis. Osteoporosis, and some of these other health factors, may well be associated with SES factors through mechanisms such as early menopause, diet, exercise, smoking, excess drinking and exposure to certain heavy metals such as lead. Height shrinkage may thus be more severe in those with current health problems or problems from early childhood, or even be correlated with pre-shrinkage height itself and with SES, leading to potentially biased estimates of the impacts of height on other health measures in OLS regressions. More to the point, there is little if any literature that explores the SES correlates of height shrinkage.

While the problem height shrinkage may cause has been considered by some researchers, there is little literature addressing it. One exception is Maurer (2010), who addressed this problem by using lower leg length as an instrument for height to address the measurement error problem, among urban elderly from Latin America and the Caribbean. Many studies exist that show a strong correlation between lower leg length, arm length and pre-shrinkage adult height (see below). For Maurer's estimator to be consistent, it is necessary that lower leg length is conditionally uncorrelated with any height shrinkage. If it is so correlated, then lower leg length will be correlated with the error term in the first stage regression, which includes shrinkage. In this case, these IV estimates will be inconsistent.

In this paper, we use both estimated pre-shrinkage height and shrinkage as covariates in OLS regressions, rather than instrumented height to tackle the problem. The first step is to estimate the pre-shrinkage height of the seniors. This issue has a long history in the nutrition and human biology literature, even, especially, using cross-section data. Limb lengths are used to predict height and the resultant prediction is used as a measure of pre-shrinkage height. This works because the limbs used in this literature do not generally shrink as people age. Lower leg length (Chumlea et al., 1985; Chumlea and Guo, 1993; Protho and Rosenbloom, 1993; Myers et al., 1994; Zhang et al., 1998; Bermudez, 1999; Li et al., 2000; Cheng et al., 2000; Pini et al., 2001; Knous and Arisawa, 2002), arm span from roughly the shoulder to the wrist (Kwok and Whitelaw, 1991; Kwok et al., 2002), total arm length (Mitchell and Lipschitz, 1982; Haboubi et al., 1990; Auyeung and Lee, 2001), upper arm or humeral length, tibia length (Haboubi et al., 1990) and fibula length (Auyeung and Lee, 2001) have all been employed to estimate pre-shrinkage stature. Most of this literature simply uses lower leg or arm length to predict height using older populations. Rarely is an attempt made to estimate shrinkage and generally no attempt is made to relate shrinkage to socio-economic variables, although see Hillier et al. (2012) for a recent, interesting exception relating shrinkage in older women to subsequent hip fractures and mortality.

Based on the national baseline data from the China Health and Retirement Longitudinal Study (CHARLS), this paper investigates the correlates of shrinkage with current SES and indicators of childhood health, and whether shrinkage is correlated with preshrinkage height. We find strong negative associations between shrinkage and current measures of SES such as level of education, log of household per capita expenditure (*pce*), urban residence, as well as strong correlations with county of current residence and province of birth. However the correlation between height shrinkage and non-location measures of childhood background are weak. We also find significant, positive correlations between shrinkage and preshrinkage height for women, suggesting that the IV strategy discussed above is not valid for women in the CHARLS data.

We then replace measured height by our pre-shrinkage height estimates, plus our estimates of height shrinkage, as covariates in regressions to investigate their associations with a rich set of later-life health variables: measures of cognitive functioning, hypertension, lung capacity, grip strength, balance, walking speed, self-reported general health, measures of physical functioning, activities of daily living (ADLs), instrumental activities of daily living (IADLs), the Center for Epidemiologic Studies- Depression (CES-D) scale and expectation of surviving to age 75 (for respondents under 65). We find that even controlling for SES and early life health conditions, that pre-shrinkage height and especially height shrinkage have significant associations with these later life health conditions. In general height shrinkage is negatively correlated with good health outcomes and pre-shrinkage height positively so. Given that height shrinkage is a marker for later-life health problems, in contrast to pre-shrinkage height which is a marker of early life health, this evidence means that it is not only early life events that are associated with late life health outcomes (childhood background variables are jointly significant in these health regressions), but health insults in later life as well. By providing the evidence of whether and how height shrinkage is correlated with health, pre-shrinkage height and SES, this paper also validates the concern raised, but not tested, by Case and Paxson (2008a) that individuals with poor health tend to shrink more than healthy ones..

This paper is organized as follows. In Section II we discuss our model and econometric framework to estimate height shrinkage and preshrinkage height. Section III discusses the data used in this paper and summary statistics. Section IV shows how we estimate the pre-shrinkage height function from a sample of "young" respondents and height shrinkage for our "older" sample. Section V discusses the evidence on the association between height shrinkage and SES and pre-shrinkage height. Section VI provides further evidence on the association between height shrinkage, pre-shrinkage height and our health measures of this older population. Section VII concludes.

II. Theoretic Framework

In previous studies, what has interested many researchers is the association between height and health status. A prototypical regression is:

$$y = x'\theta + p\alpha + u \tag{1}$$

in which y stands for health variables like self-reported health, ADL disability or cognitive ability; p is respondents' preshrinkage height; x is short for a set of co-variates, such as demographic variables, possibly SES, or perhaps other childhood health variables; u is the error term, which is assumed in the literature to be mean independent of height and control variables. We also assume that it is mean independent of the predictors of pre-shrinkage height.[1] Most researchers are interested in the coefficient α. However, in most situations, pre-shrinkage height is unobserved and the interviewers have available only measured height (h), which might have been contaminated by height shrinkage (s). The regression thus estimated is:

[1] Of course even height, though predetermined, will be correlated with unobserved variables so that the regression coefficients in (1) are not causal effects.

$$y = x'\widetilde{\theta} + h\widetilde{\alpha} + \widetilde{u} \tag{2}$$

and for the older population measured height (h), as an identity equals pre-shrinkage height (p) minus height shrinkage (s) (in the younger sample, in principle, measured height equals preshrinkage height):

$$h \equiv p - s \tag{3}$$

Height shrinkage may be independent of pre-shrinkage height, which is easier to handle, but this may not be the case. On the one hand, pre-shrinkage height is a marker of early life health status, and healthier people might shrink less with aging, have less osteoporosis for example. On the other hand, taller people may lose more height if they suffer kyphosis or some other related diseases. In these situations, the coefficients on height and x in (2) are a biased estimate of the coefficients on preshrinkage height and x in (1) because the error in (2) will contain shrinkage that is correlated with pre-shrinkage height and x.[2]

Maurer (2010) assumed that lower leg length was correlated with pre-shrinkage height and not correlated with height shrinkage, and used lower leg length as an instrument for measured height. Then he argued that the 2SLS estimation would give consistent results. However, if pre-shrinkage height is correlated with height shrinkage conditional on control variables and error term, then this 2SLS estimate will also be inconsistent.

[2] In Section V, we will provide some evidence that height shrinkage is correlated both with SES and with pre-shrinkage height, thus with the error term, ε.

In this paper, we use lower leg length and upper arm length to predict pre-shrinkage height using different data on a younger population, instead of taking them as instruments directly. We use estimates of this height function to predict pre-shrinkage height and height shrinkage for respondents from an older population, aged 60 and over.

Firstly, we estimate the following equation for the younger group:

$$h_y = z_y'\gamma + \eta_y \tag{4}$$

where z is a vector representing lower leg length, upper arm length (as an adult) and a Han ethnic dummy. The variables in x and z overlap because of the Han dummy, but there are variables (the limb lengths) in z that are excluded from x. We assume

$$\mathbb{E}(\eta_y | z_y, x_y) = 0$$

We then apply the estimated γ coefficients to the older age-group to estimate their pre-shrinkage height:

$$\widehat{p_o} = z_o'\widehat{\gamma} \tag{5}$$

Height shrinkage is defined as the difference between pre-shrinkage height and measured height, as in (3).

After estimating pre-shrinkage height and height shrinkage, we estimate the association between height shrinkage and SES variables, i.e. education levels, per capita *pce*, age dummies, living in an urban area, marital status and childhood background variables: having an urban childhood upbringing, schooling of each parent, whether each parent had died before the respondent was 18, a self-reported general health measure of the respondent's health before age 16 and dummies for province of birth.[3] In a second specification we add pre-shrinkage height. That is:

$$s = x'\beta + p\delta + \varepsilon \tag{6}$$

with $\mathbb{E}(\varepsilon|x, p, z) = 0$. Finally, we estimate (1) and (2), along with (7) below, to examine the associations between height and health:[4]

$$y = x'\theta + p\alpha + s\kappa + u \tag{7}$$

Separate OLS estimation of (4) and (6), or (4) and (7), is the optimal 2-step GMM estimator. Our standard errors for (1), (6) and (7) are corrected for the fact that we use predicted variables as dependent and/or independent variables. We derive the asymptotic variances in the appendix.

[3]The childhood background variables might be thought of as possible instrumental variables for limb lengths in (4), however this would require the assumption that the only influence of childhood background on pre-shrinkage height, height shrinkage and other height outcomes, is through limb lengths, which is not consistent with the recent literature on early childhood-later life health associations. In results not shown, apart from women having an urban upbringing for upper arm length, only the province of birth dummies are significantly related to limb lengths, among the childhood background variables available to us.

[4]Note that if we estimated (1), estimating pre-shrinkage height on the older sample, we would be using 2SLS, as in Maurer (2010). We would face the same issues we raised above.

III. Data

The China Health and Retirement Longitudinal Study (CHARLS) was initiated to study the elderly population of China. It is designed to be complementary to the Health and Retirement Study (HRS) in the United States and like surveys around the world. CHARLS covers 150 counties randomly chosen across China. Twenty-eight provinces are represented in the data.[5] Counties were grouped into 8 geographic regions, and stratified by rural/urban status and by per capita county GDP.[6] Counties were then sampled, stratified, with probability proportional to population (pps).[7] Within counties we sampled three administrative villages or urban neighborhoods (resident committees) as our primary sampling units (psu), again using pps.[8]

The sampling goal within primary sampling units was 24 households with an age eligible member, defined as a person aged 45 or older. Sampling rates varied by psu. We first mapped all of the dwellings in the psu, using Google Earth maps, adjusted from the ground by our mapping teams.[9] From this we obtained a sampling frame of dwelling doors. We then randomly sampled 80 doors, and

[5] Tibet was excluded from the study. Two other provinces, Hainan and Ningxia, both very small in population size, are not represented among the CHARLS counties..

[6] Data sources were the *Population Statistics by County/City of PRC*, 2009 (data from 2008) and the provincial statistical yearbooks (for GDP per capita).

[7] This was done by listing the stratified counties and selecting counties with a fixed interval and random starting point. This way we ensure that all parts of the GDP per capita distribution are covered.

[8] Data on population sizes were provided by the National Bureau of Statistics (NBS).

[9] CHARLS mapping staff first went to the areas with GPS devices and took readings of the administrative boundaries, which were used to extract the Google Earth maps. A few primary sampling units had unreadble or no Google Earth maps, in which case we constructed the maps from the ground. In all cases we checked the maps from the ground and added to them when they were not up to date.

obtained information on the age of the oldest person and whether the dwelling was vacant (which some were). Using this information, we calculated age eligibility rates. From this information we determined psu-specific sampling rates to ensure in expectation 24 age-eligible households and re-sampled from the initial dwelling list. If a dwelling had multiple households living in it, we randomly sampled one with an age-elgible person. Households were defined as living together, sharing meals and at least some other expenses. After sampling our final list of households, we again checked for age eligibility and then randomly sampled one person age 45 or over, and their spouse (no matter the age), as our respondents.

The national baseline was fielded from late summer 2011 until March 2012 (see Zhao et al., 2012, for details). Among all households, the age eligibility rate was 62% and the response rate among eligible households was 84%; 90% among rural households and 77% for urban households.[10] These rates compare very well with other HRS surveys in their initial waves. Sample size is 17,085 individuals with non-missing ages.

We use two samples for this paper. We estimate our preshrinkage height prediction equation using a "young" sample of respondents and spouses aged 45-49, who have presumably not started to shrink yet, or if so, have only shrink a very small amount on average. We then use respondents and spouses aged 60 and over to predict preshrinkage heights, calculate shrinkage and estimate our models. Of the 17,085 observations, 3,027 are between 45 and 49 and 7,611 are 60 and over. Approximately 15% of "young" respondents did not get their biomarkers taken,

[10] Of those who did not respond, about half refused and half could not be found.

usually because they were busy at work and unavailable. Among the "old" sample, 18% did not get any biomarkers taken, usually because they were too frail to be measured. Non-measurement rates were higher among those over 80 years. In addition, some observations were dropped because they had missing heights or other key variables missing or out of reasonable range. We are left with 1,101 men and 1,508 women in the "young" sample and 2,940 men and 2,928 women in the "old" sample, who have complete height and limb measurements (fewer with all of the other health variables complete).

Anthropometric measures included respondent's standing height, upper arm length and lower leg length, all measured in millimeters. The summary statistics of these variables are shown in Panels A and B of Table 1 for the "young" and "old" samples, respectively. Height was measured using a stadiometer directly from the heel to the top of head with the elders standing up-right. Upper arm length was measured with a Martin caliper with the respondent standing and holding the left or right arm at a right angle. We measured from the acromion process of the scalpula to the olecranon process. Lower leg length was also measured using a Martin caliper from the right knee joint to the ground. Measured heights are smaller for the older group, by some 4 cm for men and 4.5 cm for women. Much of this difference could be due to shrinkage, although it could also be that older birth cohorts were less tall. Comparing upper arm lengths, they are very close between the 45-49 and 60 and over groups, suggesting that shrinkage may be the more important explanation. On the other hand, lower leg lengths are about 0.6 cm smaller for the over 60 group, for both men and women, suggesting some possible cohort effects.

As mentioned above, this study examines the associations between pre-shrinkage height and height shrinkage on different measures of health of older people. We start with cognition questions, which are grouped into three, following McArdle (2010) and Smith et al. (2011). The first component is the Telephone Interview of Cognitive Status (TICS). There are ten questions in this part, from awareness of the date (using either solar or lunar calendar), the day of the week and season of the year, to successively subtracting 7 from 100. An index is formed of the number of correct answers. This is a measure of the mental intactness of the respondent (Smith et al., 2011). A second set of questions asks a respondent to recall a series of 10 simple nouns and to recall again after approximately 10 minutes. Following McArdle (2010), we average the number of correct answers as our dependent variable. This is a measure of episodic memory, and is a component of fluid intelligence (Smith et al., 2011). Finally respondents are shown a picture of two overlapping pentagons and asked to draw it. We score the answer as 1 if the respondent successfully performs this task.

We have several biomarker variables available. We measure blood pressure three times. We create a dummy variable equal to one if a respondent has hypertension. For this case we take means of systolic and diastolic measurements and assign a hypertensive status equal to one if mean systolic is 140 or greater or if mean diastolic is 90 or greater. In addition respondents self-report if they have been diagnosed by a doctor with hypertension and we include those cases as being hypertensive. Respondents blow into a peak flow meter three times to measure lung capacity and we take the average. Respondents have their grip strength measured by a dynamometer. Two measurements are taken from each hand. We use average measurement from the self-reported dominant hand. Respondents are given a balance test, whether they can stand semi-tandem or full tandem. Because most can stand full tandem, we create a dummy equal to 1 if they can do so.[11] Finally we conduct a timed walk of 4 meters, asking the respondent to walk at a "normal" speed.

The remaining health measures are self-reported. General health is reported on a scale: very good, good, fair, poor, very poor. We construct a binary variable equal to one if health is reported as very poor or poor, zero otherwise. Respondents are asked about whether they have difficulty in performing certain classes of activities: physical functioning, ADLs and IADLs.[12] We count the number of items in each group that the respondent claims having difficulty in performing or cannot perform. The expected survival question asks respondents to rank their expectation of surviving to a specific older age on a five point scale, from almost impossible to almost certain. We group the bottom two answers, almost impossible and not very likely. Because different age groups are asked survival chances to different ages, we standardize by only using those respondents under age 65, who are asked their survival chances to age 75. Similarly, respondents answered a Chinese version of CES-D 10 questionnaire in the survey, which

[11] Respondents under 70 are asked to stand in full tandem for 60 seconds, those 70 and over for 30. We include age dummies as covariates, which will capture this difference.

[12] There are nine questions on physical functioning, ranging from having difficulty running or jogging 1 km, to walking 1 km, tocarrying a heavy bag of groceries, to picking up a small coin. There are 6 ADL questions(eg. getting into and out of bed or using the toilet) and 5 IADL quesitons (eg. doing household chores, shopping, or managing money).

contained 10 questions about the respondents' depression status. Based on that, we constructed a CES-D scale, with range from 0 to 30.

Mean values and standard deviations of all the health variables are provided in Panel B of Table 1 for the "old"sample. As is generally the case, health measures for older women are worse than for men. This is true both for self-reported measures such as poor general health, difficulties with physical functioning or ADLs, and the CES-D depression scale, and for biomarkers such as hypertension, the cognition measures, grip strength and lung capacity.

Panel B also reports summary statistics of demographic variables like education level, log of household per capita expenditure (*pce)*,[13] marital status and type of areas (urban/rural) where respondents live at the time of the survey. The current generation of elderly population in China has only a small amount of schooling, particularly among women. Fifty-five percent of women 60 and over are illiterate, twenty percent among men. Only 8% of older men and 3% of women have completed senior high school or more. However, 56% of men have completed primary school, and 35% of women. When we compare these numbers to the parents of these elderly, some progress had been made, since over 70% of fathers and 90% of mothers are reported to be illiterate (no schooling or less than primary school completion-see Panel B). The preponderance of our respondents are still married, more so among men, since their spouses tend to be younger. An overwhelming majority, over 80% of older men and women, live in rural areas.

[13] Per capita expenditures include the value of food consumed from own production. We prefer *pce* to income because *pce* is measured with less error and better represents long-run resources, since households smooth their consumption over time.

Childhood background variables are also reported in Panel B. An even larger percent, over 90, have a rural background as a child. About 10-12% of fathers died before the respondent was age 18 and about 6-7% of mothers. CHARLS has a retrospective question about general health before the respondent turned 16 (an average over that period), with categories excellent, very good, good, fair or poor. This has been successfully used by HRS and other aging surveys, including the CHARLS pilot, and has been linked to later life health outcomes (e.g. Smith, 2009). In the CHARLS sample, 6% of men and 9% of women report that their childhood health was poor. Finally CHARLS also elicits province of birth. Evidence on public health infrastructure for pre-revolutionary China is scant, but some evidence exists that in Beijing, better water and sanitation facilities were built between 1910 and 1920 (Campbell, 1997) and that led to a rapid decline in infant mortality in there. This would have affected our cohorts. For other major cities there is some, but not much, evidence that public health infrastructure was being built during that time period (Campbell, 1997).

IV. Estimation of Pre-shrinkage Height

Following the methodology in the medical literature, we use lower leg length and upper arm length and estimate gender-specific equations using measured height as the dependent variable. Additionally, we add quadratics in both limb lengths and interactions to allow for nonlinearities. We also add a Han dummy variable to pick up potential ethnic differences.[14]

[14] Ethnic differences in the proportions of limb lengths to height have been found in the literature (see Steele, 1987, for example). Age is not included. Age itself should only have an influence on

The steps to estimate pre-shrinkage height is as follows: first, we use data from the "young" group, aged 45-49, and regress measured height on lower leg length, upper arm length, their squares and interaction and the Han dummy. These coefficients are then applied in the "older" sample, those aged 60 and above, and the predicted value is the estimated pre-shrinkage height for this group. Some medical studies have used this approach, separating "young" and "old" groups, include Steele (1987) and Reeves et al. (1996).[15] A strong assumption is required that any secular changes in height across birth cohorts (which are important in China) do not change the relationship between height and limb length (see Leung et al., 1996 and Kwok et al., 2002).[16] The regressions are shown in Table 2.

Columns (1)-(3) in Table 2 show the coefficients of the pre-shrinkage height function in the male sample and columns (4)-(6) for the female sample. We first show a linear specification in limb lengths and the Han dummy, then add quadratics and an interaction, and finally a linear time trend. The quadratics and interaction are always jointly significant at under .001, while the time trends are not significant at standard levels; hence we use columns (2) and (5) as our preferred estimates. The marginal effects on height of both lower leg and upper arm lengths are positive over the entire distribution, and convex. The Han dummy is positive

pre-shrinkage height through birth cohort effects. These are likely but the sample we estimate our coefficients for only spans 10 years. We do try one specification that includes a linear trend in year of birth, but it is never significant at standard levels.

[15] However, most of the medical literature estimates the coefficients using the same age-group sample as is used to predict preshrinkage height.

[16] Kwok et al. (2002) use data on an older sample in China to estimate their prediction equation, but they first remove observations who have symptoms of vertebral deformity based on x-ray images. They find the same ratio of total arm span to height for younger and older men, but a slightly higher ratio for older women.

for both men and women, but significant (at 5%) only for women. The R^2's are over .51 for both men and women.[17]

After we obtain our pre-shrinkage height estimates for the 60 and older group, height shrinkage is defined as the estimated pre-shrinkage height less the current measured height. The summary of our estimates are shown in Panel B in Table 1. Mean height shrinkage is 3.3 cm for men and 3.8 cm for women, which is consistent with findings in the human biology literature that women have more problems with vertebral deformity (see Kwok et al., 2002).

Figure 1 shows the age pattern of measured height, pre-shrinkage height and height shrinkage by gender. The top two figures show non-parametric graphs of measured height and pre-shrinkage height as a function of age. And the bottom two graphs show the pattern of height shrinkage and age for males and females respectively.[18] From the top two graphs, estimated pre-shrinkage height does not decline much with age, a little more for men than for women. However measured height does decline with age, indicating that height shrinkage increases, as shown in the bottom two figures. Our pre-shrinkage height estimates do not correct for mortality selection. If we assume that respondents who survived to older ages are those who were taller and less frail, then adding those who died back would result in pre-shrinkage heights declining with age. This is what we would expect if older birth cohorts faced worse health conditions at birth, and in early life.

[17] Many of the medical papers obtain higher R^2s for their height prediction equations, but they generally have extremely small samples and extrememly controlled circumstances in which the measurements are conducted, which should minimize measurement error, compared to a large-scale population survey such as CHARLS..

[18] The non-parametric curves are calculated using a Jianqing Fan (1992) locally weighted regression smoother, which allows the data to determine the shape of the function.

As a check on our preshrinkage height estimates, we compare our CHARLS preshrinkage heights for the sample aged 60-69 in 2011, by year of birth, to measured heights in another data source, the China Health and Nutrition Survey (CHNS). We use the same birth year cohorts in both data sets, but in the CHNS data, we can measure heights of these cohorts 20 years earlier, in 1991, when they would be aged 40-49, and so should not have begun to shrink much yet. We thus expect their measured heights in 1991 to be close to our estimated preshrinkage heights in the CHARLS data for the same birth year cohort.[19] The CHNS data in 1991 only covers 8 provinces, not 28 provinces as in CHARLS, and so is not representative of all of China, in contrast to CHARLS, which should be born in mind. We use the entire CHARLS sample for comparison in order to have a larger sample size. The results are shown in Appendix Table 1. Comparing mean heights by birth year cohort between being measured in 1991 in CHNS and in 2011 in CHARLS, heights in 1991 are higher, by 1.5-4 cm, depending on the age, which is consistent with shrinkage. Comparing mean heights in 1991 with estimated preshrinkage heights from CHARLS, the results show a close correspondence. For women, the differences between the CHARLS estimated preshrinkage heights and the CHNS measured heights is very small, generally under 0.7cm and often less than 0.5cm. For men, aged 60-64 in 2011 (40-44 in 1991), the differences are very small as well; they increase some for those aged 65-69 in 2011, which may indicate

[19] We thank David Cutler for this idea. Note that the CHNS data do not include limb lengths, so we cannot use the CHARLS preshrinkage height function estimates to predict individual preshrinkage heights with CHNS observations. Also only one height observation per person is available in CHNS, so it is not possible to take differences in height measurements to measure shrinkage directly.

that there is some shrinkage that has begun in this age group.[20]

V. Height Shrinkage, Pre-Shrinkage Height and SES

Very few studies have been able to measure height shrinkage and we know precious little about the correlations between shrinkage and later life SES, early life health conditions and family background. Further, as noted, any correlations between height shrinkage and upper arm and lower leg length are important since they determine whether an IV estimator using lower leg and upper arm lengths as IVs for measured height in health equations is consistent. Table 3 shows the gender-specific results of the association between SES, early life conditions, upper arm and lower leg length, and height shrinkage. All regressions control for basic demographic variables, including dummy variables for age, Han ethnicity, marital status, urban residence and current residential county. We also include covariates measuring early life conditions, including dummies for province of birth, urban upbringing before age 16, for schooling of the father and mother, for whether the father and mother died by respondent's age 18, and for whether the respondent reported being in poor health on average before age 16. In columns 2 and 4 we add preshrinkage height. All estimates correct standard errors for the fact that we predict shrinkage and pre-shrinkage heights (see the Appendix for detailed derivations).

From these estimates, we find that the SES variables are very important predictors of height shrinkage; the Wald tests are all highly significant. Dummy

[20] Plotting the ratio of lower leg or upper arm length to measured height in the CHARLS data does show a slight increase for those in their late 40s, which is consistent with this conjecture.

coefficients of level of education are negative, monotonically declining with higher education and jointly significant. One potential explanation can be that people with higher education level are more likely to have had better health behaviors when younger. They are also likely to have had better health during childhood, perhaps in ways not measured by our childhood general health variable. Household log *pce* is negatively associated with height shrinkage, especially for men, indicating that higher income people may be able to purchase better medical care and nutritious food for themselves, although there is likely to exist reverse causality as well, which may explain why the coefficients are more negative for men. Being currently married is associated with less shrinkage for men, but not significant. Marriage is often found to be correlated positively with better health and more happiness, and is associated with better labor market outcomes for men, so this is not surprising, though, again, we must remember that these estimates are not necessarily causal. Not surprisingly, there are very strong positive associations between shrinkage and age. Currently living in an urban area is significantly associated with less shrinkage for both men and women. The county dummies are jointly significant at under the .001 level. This is consistent with results such as Strauss et al. (2010), who find very strong community effects on health outcomes for the elderly in China, using the CHARLS Pilot data. Early childhood background and health are not jointly significant in these regressions. However, having had poor childhood health is associated with more shrinkage for women, significant at 10%. Dummies for birth provinces are jointly significant, for both men and women.

Table 3 also demonstrates positive and significant correlation between height shrinkage and preshrinkage height for women, although not for men. This is different from the results of Kwok et al. (2002), who find a weak negative correlation for men; although those results are bivariate, not multivariate, controlling for SES variables, as ours. This implies that lower leg and upper arm length fail the IV requirement for women, that they be uncorrelated with the error term (which includes shrinkage) in a health equation with measured height as a covariate.

VI. Results: Impact of Estimated Height on Health Outcomes

Since there is a growing literature, cited above, that investigates how height is associated with other adult health outcomes, it is of interest to explore this with our estimates of preshrinkage heights and height shrinkage. We do not claim causality from these regressions, because of the usual problem of omitted variables, but also because in some instances reverse causality is possible.[21] The procedure is to regress our health measures first on measured height and control variables to get our baseline estimates. Then we replace measured height by predicted pre-shrinkage height and finally add height shrinkage. Standard errors are again corrected for predicted shrinkage and preshrinkage heights. Since some health outcomes are missing for some observations, the number of observations differs by outcome.

Table 4.1-4.3 show the results from the regressions of our health measures on

[21] One potential example is with the depression score and shrinkage. Depression is associated in women with early menopause. Menopause in turn is associated with osteoporosis, which can lead to shrinkage. Now our depression score is current and may not indicate past episodes, but we also know that if a person has had one bout of depression, that increases the likelihood of more, later.

height. The same demographic and SES controls, and controls for early life conditions that we use in Table 3 are added in all the regressions. We start with the cognition outcomes in Table 4.1. Measured height is positively and significantly associated with all of the cognition measures for both men and women. Case and Paxson (2008a) find such relationships among the older population in the United States using the Health and Retirement Study (HRS) (see Smith et al., 2012 for evidence on China). A likely mechanism for this relationship is the positive association between childhood height and childhood and later cognition. There exists a large literature on early child height impacts on later child cognition; Case and Paxson (2008b) is a recent example (see Glewwe and Miguel, 2008 and Strauss and Thomas, 2008 for reviews). Since childhood heights are strongly related to adult heights and cognition skills persist from childhood through adulthood, it is not surprising to see this relationship among older persons. When we replace measured heights by preshrinkage heights and height shrinkage, preshrinkage height has the same positive, significant association with the TICS and draw a picture variables, though not for the word recall. Height shrinkage is, however, strongly, negatively correlated with all of these measures and for both men and women, suggesting that a part, perhaps a large part, of the association between measured height and cognition occurs through height shrinkage. As we saw in Table 3, shrinkage is highly associated with many current SES variables and with some childhood background factors having to do with province of birth, and for women, health as a child, but not with other measured childhood background factors. Current and childhood SES and childhood health variables are each jointly significantly associated with the cognition outcomes, as are the current county of residence dummies and, for women, the birth provinces. So these results imply that later life cognition and health is associated with health events throughout the life cycle and in later life, not just from early childhood.

In Table 4.2 we show results for the biomarkers. Preshrinkage height is significantly, positively related to lung capacity and grip strength, and height shrinkage is significantly, negatively related to both outcomes. Men who have shrunk more take more time to do the timed walk, but for women shrinkage and preshrinkage heights are not related to walk time. Hypertension and ability to balance are also unrelated to both preshrinkage height and shrinkage. Current and childhood SES are related to many of these outcomes, as are current county of residence and province of birth.

Table 4.3 has results for self-reported health outcomes. As can be seen, shrinkage is generally related to worse outcomes. For men, this is so for the CES-D depression index, the likelihood of not surviving to age 75 (for those 65 and younger), the number of measures of physical functioning that the respondent reports having difficulty with, and having poor or very poor general health. For women, shrinkage is significantly associated with having more difficulties with measures of physical functioning, ADLs and IADLs. What is surprising about these results is that preshrinkage heights sometimes have positive associations with bad health outcomes for women, although not for men. This is very unlike the results for cognition and the biomarkers. Mortality selection could be partly causing this, but we cannot be more than speculative on this point.

VII. Conclusions

According to Barker (1994), childhood health in uterus has a lasting impact on health, including at old ages. Height has been used widely as an indicator in part of childhood health. However, because height shrinks with aging, it suffers a measurement error problem when studying its impact on health outcomes at older ages.

Based on unique data of Chinese aged 45 and older, we address this problem by making use of upper arm and lower leg lengths to construct estimates of the relationship between these limb lengths and measured height, on a population aged 45-49, and then use these estimates to estimate preshrinkage height and height shrinkage on a population 60 years and older. We then investigate the association between height shrinkage, SES variables and variables measuring different dimensions of childhood health. We follow this exercise by examining the associations between measured height on the one hand, or pre-shrinkage height and shrinkage on the other, and a rich set of health variables, including measures of cognition, biomarkers, as well as various self-reported health measures.

The results in this paper show that shrinkage and socio-economic variables such as schooling and household per capita expenditure are negatively correlated for both men and women. Shrinkage is somewhat larger for women, which is consistent with the medical literature. Shrinkage also depends positively on pre-shrinkage height for women, which rules out a potential instrumental variables strategy to correct measured height for omitted variables bias when it is used as a covariate explaining other health variables, supporting the concern expressed in

Case and Paxson (2008a). Height shrinkage, and to a lesser extent, pre-shrinkage height, are also correlated with many later life health outcomes, particularly cognition and biomarker measures. In general the more the shrinkage the worse are these other health outcomes.

Appendix: Asymptotic Variances

Table 3 uses a constructed dependent variable, height shrinkage, while Tables 4.1-4.3 use predicted preshrinkage height and, in some specifications, height shrinkage, as right hand side variables. Furthermore, the predicted preshrinkage height coefficients are derived from a different sample. This suggests that a 2 sample GMM procedure might be appropriate (eg. Ridder and Moffitt, 2007), however we are not using the standard setup because we do not use all of the variables in the second stage to predict preshrinkage height. We derive the asymptotic variances here.

Shrinkage as dependent variable

The regression with shrinkage as the dependent variable is

$$s = x'\beta + p\delta + \varepsilon$$

with $\mathbb{E}(\varepsilon|x,p,z) = 0$. Substitution of (4) gives

$$z'\gamma - h = x'\beta + z'\gamma\delta + (\delta - 1)\eta + \varepsilon = x'\beta + z'\gamma\delta + \zeta$$

with $\zeta = (\delta - 1)\eta + \varepsilon$. Rearranging gives

$$-h = x'\beta + z'\gamma(\delta - 1) + \zeta = x'\beta + z'\gamma\alpha + \zeta$$

Note that $\alpha = -1$ if pre-shrinkage height is not in the relation.

This equation is estimated on the older sample with γ being estimated on the younger sample. The unconditional moment restrictions are

$$\mathbb{E}_O\left[\begin{pmatrix} x \\ z \end{pmatrix}(-h - x'\beta - z'\gamma\alpha)\right] = 0$$

$$\mathbb{E}_Y[z(p - z'\gamma)] = 0$$

Define

$$m_O(\beta,\alpha,\gamma) = \begin{pmatrix} x \\ z \end{pmatrix}(-h - x'\beta - z'\gamma\alpha)$$

$$m_Y(\beta,\alpha,\gamma) = z(p - z'\gamma)$$

We have

$$\mathbb{E}_O[m_O(\beta_0,\alpha_0,\gamma_0)m_Y(\beta_0,\alpha_0,\gamma_0)'] = 0$$

so that the variance matrix of the moment conditions is

$$W = \begin{pmatrix} \sigma_\zeta^2\mathbb{E}_O(xx') & \sigma_\zeta^2\mathbb{E}_O(xz') & 0 \\ \sigma_\zeta^2\mathbb{E}_O(zx') & \sigma_\zeta^2\mathbb{E}_O(zz') & 0 \\ 0 & 0 & \sigma_\eta^2\mathbb{E}_Y(zz') \\ \end{pmatrix}$$

with estimator

$$\hat{W} = \begin{pmatrix} \hat{\sigma}_\zeta^2\frac{X_O'X_O}{N_1} & \hat{\sigma}_\zeta^2\frac{X_O'Z_O}{N_1} & 0 \\ \hat{\sigma}_\zeta^2\frac{Z_O'X_O}{N_1} & \hat{\sigma}_\zeta^2\frac{Z_O'Z_O}{N_1} & 0 \\ 0 & 0 & \hat{\sigma}_\eta^2\frac{Z_Y'Z_Y}{N_2} \\ \end{pmatrix}$$

where X_O, Z_O are the matrices with covariates for the old sample and Z_Y is the matrix with covariates of the young sample.

The inverse of $\hat{W}$ is block diagonal and that implies that the optimal GMM estimator with weighting matrix $\hat{W}^{-1}$ is the solution to

$$X_O'(-h_O - X_O\beta - Z_O\gamma\alpha) = 0$$

$$Z_O'(-h_O - X_O\beta - Z_O\gamma\alpha) = 0$$

$$Z_Y'(p_Y - Z_Y\gamma) = 0$$

Therefore the optimal GMM estimator regresses p on z in the young sample and uses these estimates in the old sample. We can therefore rewrite the moment function for the old sample as (we use the same notation for the moment function)

$$m_O(\beta, \alpha, \gamma) = \begin{pmatrix} x \\ z'\gamma \end{pmatrix} (-h - x'\beta - z'\gamma\alpha)$$

and use unweighted GMM.

To obtain the asymptotic variance we first compute

$$\begin{aligned}
\frac{\partial m_O}{\partial \beta'}(\beta, \alpha, \gamma) &= -\begin{pmatrix} x \\ z'\gamma \end{pmatrix} x' \\
\frac{\partial m_O}{\partial \alpha}(\beta, \alpha, \gamma) &= -\begin{pmatrix} x \\ z'\gamma \end{pmatrix} z'\gamma \\
\frac{\partial m_O}{\partial \gamma'}(\beta, \alpha, \gamma) &= -\begin{pmatrix} x \\ z'\gamma \end{pmatrix} \alpha z' + \begin{pmatrix} 0 \\ z' \end{pmatrix} (-h - x'\beta - z'\gamma\alpha) \\
\frac{\partial m_Y}{\partial \beta'}(\beta, \alpha, \gamma) &= 0 \\
\frac{\partial m_Y}{\partial \alpha}(\beta, \alpha, \gamma) &= 0 \\
\frac{\partial m_Y}{\partial \gamma'}(\beta, \alpha, \gamma) &= -zz'
\end{aligned}$$

The variance matrix of

$$\begin{pmatrix} \hat{\beta} \\ \hat{\alpha} \\ \hat{\gamma} \end{pmatrix}$$

is

$$(A'W^{-1}A)^{-1}$$

with

$$A = \begin{pmatrix} -\mathbb{E}_O(xx') & -\mathbb{E}_O(xz')\gamma & -\mathbb{E}_O(xz')\alpha \\ -\gamma'\mathbb{E}_O(zx') & -\gamma'\mathbb{E}_O(zz')\gamma & -\gamma'\mathbb{E}_O(zz')\alpha \\ 0 & 0 & -\mathbb{E}_Y(zz') \\ \end{pmatrix}$$

and (using the same notation for the variance of the new moment conditions)

$$W = \begin{pmatrix} \sigma_\zeta^2\mathbb{E}_O(xx') & \sigma_\zeta^2\mathbb{E}_O(xz')\gamma & 0 \\ \sigma_\zeta^2\gamma'\mathbb{E}_O(zx') & \sigma_\zeta^2\gamma'\mathbb{E}_O(zz')\gamma & 0 \\ 0 & 0 & \sigma_\eta^2\mathbb{E}_Y(zz') \\ \end{pmatrix}$$

Now

$$A'W^{-1}A = \begin{pmatrix} \sigma_\zeta^{-2}\mathbb{E}_O(xx') & \sigma_\zeta^{-2}\mathbb{E}_O(xz')\gamma & \sigma_\zeta^{-2}\mathbb{E}_O(xz')\alpha \\ \sigma_\zeta^{-2}\gamma'\mathbb{E}_O(zx') & \sigma_\zeta^{-2}\gamma'\mathbb{E}_O(zz')\gamma & \sigma_\zeta^{-2}\gamma'\mathbb{E}_O(zz')\alpha \\ \sigma_\zeta^{-2}\mathbb{E}_O(zx')\alpha & \sigma_\zeta^{-2}\mathbb{E}_O(zz')\gamma'\alpha & \sigma_\eta^{-2}\mathbb{E}_Y(zz') + \sigma_\zeta^{-2}C \\ \end{pmatrix}$$

with

$$C = \alpha^2 \begin{pmatrix} \mathbb{E}_O(zx') & \mathbb{E}_O(zz')\gamma' \\ \end{pmatrix} \begin{pmatrix} \mathbb{E}_O(xx') & \mathbb{E}_O(xz')\gamma \\ \gamma'\mathbb{E}_O(zx') & \gamma'\mathbb{E}_O(zz')\gamma \end{pmatrix}^{-1} \begin{pmatrix} \mathbb{E}_O(xz') \\ \gamma'\mathbb{E}_O(zz') \end{pmatrix}$$

If pre-shrinkage height is excluded, i.e. $\alpha = -1$ the second row and column in $A'W^{-1}A$ are removed, we substitute $\alpha = -1$, and

$$C = \mathbb{E}_O(zx') \left(\mathbb{E}_O(xx')\right)^{-1} \mathbb{E}_O(xz')$$

The resulting variance matrix is for

$$\begin{pmatrix} \hat{\beta} \\ \hat{\gamma} \end{pmatrix}$$

We estimate $\mathbb{E}_O(xx')$ by

$$\frac{X_O' X_O}{N_1}$$

and same for other moments for the older population. For the younger population we estimate $\mathbb{E}_Y(zz')$ by

$$\frac{Z_Y' Z_Y}{N_2}$$

The variances σ_η^2 and σ_ζ^2 are estimated in the usual way. Note that we do not have to make an assumption on the correlation of η and ε for the older population (which would not be identified).

Pre-shrinkage height and shrinkage as independent variables

The basic regression is now:

$$y = x'\theta + p\alpha + s\kappa + u$$

with $\mathbb{E}(u|x,p,s) = 0$. Substitution of the prediction equation gives

$$y = x'\theta + z'\gamma\alpha + (z'\gamma - h)\kappa + (\alpha + \kappa)\eta + u = x'\theta + z'\gamma(\alpha + \kappa) - h\kappa + (\alpha + \kappa)\eta + u = x'\theta + z'\gamma\mu + h\nu + \zeta$$

with $\mu = \alpha + \kappa$ and $\nu = -\kappa$ and $\zeta = \mu\eta + u$.

If we read for x' the vector $(x' \ h)$ and for β' the vector $(\theta' \ \nu)$ and for δ the parameter μ, then we see that the variance matrix in the previous section applies with these changes (if we use the same estimator). This gives us the variance matrix of

$$\begin{pmatrix} \widehat{\theta} \\ \widehat{\nu} \\ \widehat{\mu} \\ \hat{\gamma} \end{pmatrix}$$

From this we easily obtain the variance matrix of the original parameters.

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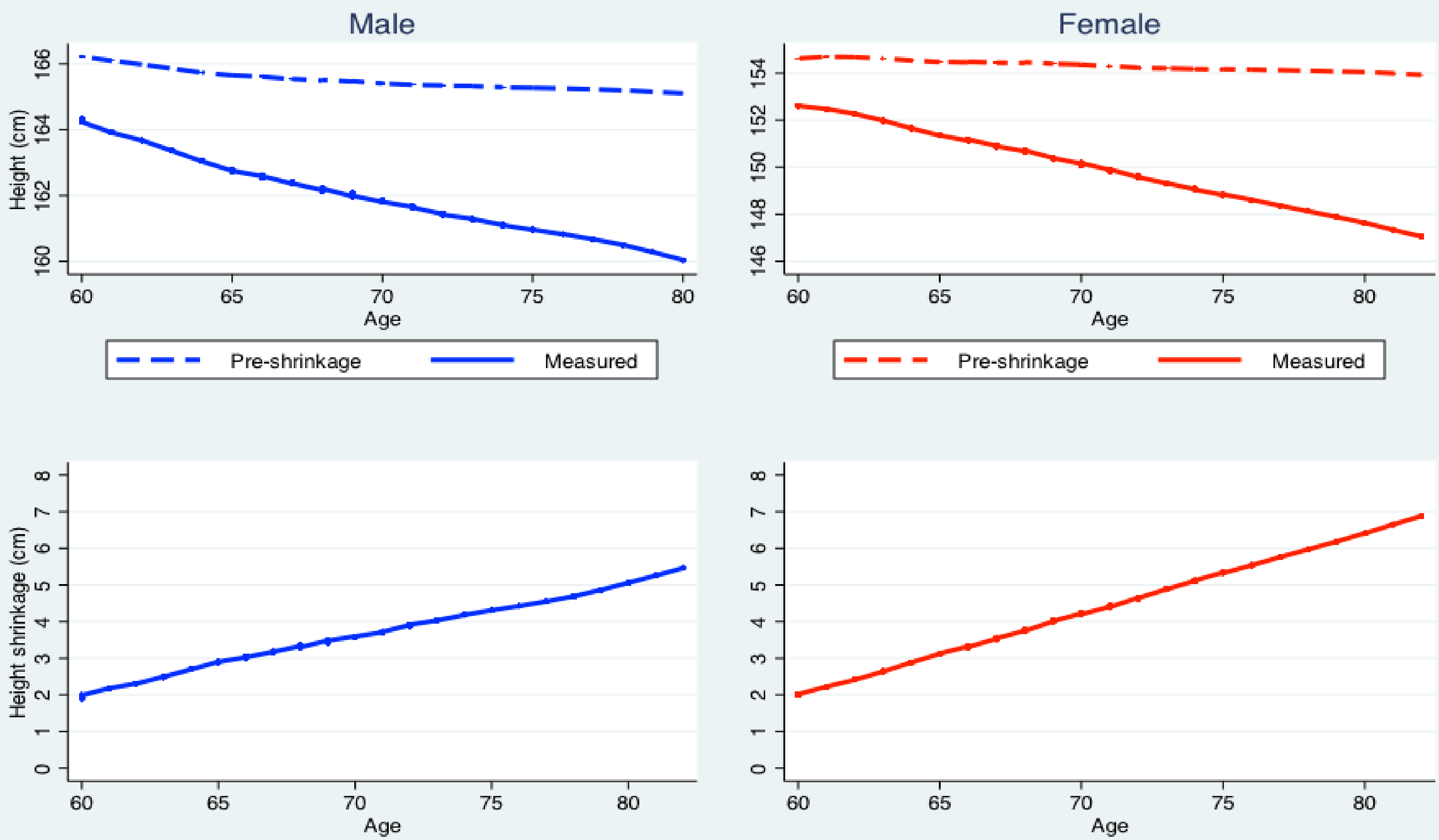
Fig 1. Measured height, pre-shrinkage height and height shrinkage



Data source: CHARLS 2011.

Table 1: Summary Statistics

Variable	Male Obs	Male Mean	Male Std. Dev.	Female Obs	Female Mean	Female Std. Dev.
Panel A: Younger sample (45 <= Age <= 49)						
Height	1101	166.35	6.16	1508	155.20	5.87
Upper arm	1101	35.20	2.37	1508	32.61	2.21
Lower leg	1101	50.00	3.09	1508	46.53	2.98
Age	1101	47.31	1.31	1508	47.25	1.35
Han	1101	0.94	0.24	1508	0.92	0.27
Panel B: Older sample (Age >= 60)						
Health Measures						
Poor general Health	2939	0.29	0.46	2926	0.36	0.48
Physical function	2728	1.13	1.40	2493	1.63	1.59
ADLs	2917	0.39	0.99	2899	0.56	1.16
IADLs	2923	0.49	1.09	2905	0.74	1.27
TICS	2927	7.17	2.71	2907	5.26	3.15
Words recall	2707	3.10	1.67	2612	2.85	1.74
Draw a figure	2927	0.64	0.48	2907	0.40	0.49
CESD	2762	8.04	5.98	2663	10.26	6.77
Life poor expectation	2588	0.33	0.47	2444	0.38	0.49
Hypertension	2927	0.47	0.50	2914	0.57	0.50
Lung capacity	2786	264.05	113.57	2666	195.13	79.41
Grip strength	2890	32.70	9.03	2840	21.69	7.34
Balance	2839	0.75	0.43	2762	0.60	0.49
Walk time	2771	4.42	2.10	2706	5.01	2.68
Biological Measures and Demographics						
Height	2940	162.32	6.77	2928	150.65	6.50
Upper arm	2940	35.22	2.38	2928	32.49	2.20
Lower leg	2940	49.45	2.92	2928	45.89	2.97
Pre-shrinkage height	2940	165.62	4.32	2928	154.43	4.07
Height shrinkage	2940	3.30	5.04	2928	3.79	5.02
Age	2940	68.05	6.42	2928	68.09	6.92
Han	2940	0.94	0.23	2928	0.93	0.25
Socio-Economic Status						
Education level						
Illiterate (Reference)	2940	0.20	0.40	2928	0.55	0.50
Primary	2940	0.56	0.50	2928	0.35	0.48
Junior	2940	0.16	0.37	2928	0.07	0.26
Senior and above	2940	0.08	0.27	2928	0.03	0.18
Log (expenditure per capita)	2940	8.34	0.91	2928	8.29	0.93
Married	2940	0.86	0.34	2928	0.71	0.46
Urban	2940	0.18	0.38	2928	0.21	0.40
Childhood Socio-Economic Status						
Urban before 16	2940	0.08	0.28	2928	0.08	0.27
Childhood Health fair and better	2940	0.93	0.25	2928	0.90	0.30
Childhood Health poor	2940	0.06	0.24	2928	0.09	0.29
Childhood health missing	2940	0.01	0.08	2928	0.01	0.10
Father illiterate	2940	0.66	0.48	2928	0.70	0.46
Father literate	2940	0.29	0.45	2928	0.24	0.43
Father education missing	2940	0.05	0.22	2928	0.06	0.24
Mother illiterate	2940	0.91	0.28	2928	0.93	0.26
Mother literate	2940	0.05	0.22	2928	0.04	0.19
Mother education missing	2940	0.04	0.18	2928	0.03	0.18
Father alive before 18	2940	0.87	0.34	2928	0.89	0.31
Father dead before 18	2940	0.12	0.33	2928	0.10	0.30
Father death missing	2940	0.01	0.10	2928	0.01	0.08
Mother alive before 18	2940	0.91	0.29	2928	0.94	0.25
Mother dead before 18	2940	0.07	0.26	2928	0.06	0.23
Mother death missing	2940	0.01	0.12	2928	0.01	0.10

Note: Data source is CHARLS 2011.

Table 2: Height Prediction

VARIABLES	(1)	**(2)**	(3)	(4)	(5)	**(6)**	(7)	(8)
	Measured Height							
	Male				Female			
Upper arm	0.694***	**-0.0819**	0.694***	-0.0714	0.773***	**-2.021***	0.776***	-1.982*
	(0.115)	**(1.712)**	(0.114)	(1.712)	(0.0948)	**(1.173)**	(0.0946)	(1.171)
Lower leg	0.996***	**-6.689*** **	0.996***	-6.684***	0.938***	**-4.140*** **	0.938***	-4.149***
	(0.105)	**(1.245)**	(0.105)	(1.246)	(0.0738)	**(1.110)**	(0.0739)	(1.110)
Arm square		**0.00268**		0.00266		**0.0565****		0.0564**
		(0.0240)		(0.0240)		**(0.0227)**		(0.0227)
Leg square		**0.0761*** **		0.0761***		**0.0636*** **		0.0639***
		(0.0122)		(0.0122)		**(0.0150)**		(0.0150)
Arm X Leg		**0.00982**		0.00963		**-0.0197**		-0.0204
		(0.0330)		(0.0330)		**(0.0222)**		(0.0222)
Han	0.397	**0.716**	0.386	0.707	1.049**	**1.252*** **	1.027**	1.230***
	(0.564)	**(0.589)**	(0.564)	(0.589)	(0.426)	**(0.409)**	(0.427)	(0.410)
Time trend (Age - 40)			-0.0384	-0.0298			-0.0909	-0.0948
			(0.104)	(0.0946)			(0.0826)	(0.0762)
Constant	91.78***	**291.4*** **	91.88***	291.2***	85.37***	**244.1*** **	85.59***	243.9***
	(4.536)	**(47.90)**	(4.538)	(47.90)	(3.268)	**(19.51)**	(3.272)	(19.52)
Observations	1,101	**1,101**	1,101	1,101	1,508	**1,508**	1,508	1,508
R-square	0.443	**0.518**	0.443	0.518	0.456	**0.517**	0.456	0.517
F test for All limbs	140.3	**136.5**	140.4	136.5	229.8	**182.0**	231.3	181.3
P Value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
F - Quadratic terms		**16.90**		16.85		**23.55**		23.43
P Value		[0.000]		[0.000]		[0.000]		[0.000]

Note: Data source is CHARLS 2011. Sample used are those aged between 45 and 49. Coefficients in Columns (2) and (6) are used to predict pre-shrinkage height in older sample.

Table 3: Preshrinkage height and SES

VARIABLES	(1)	(2)	(3)	(4)
	Height shrinkage (cm)			
	Male Sample		Female Sample	
Pre-shrinkage height (cm)		0.008		0.046*
		(0.0275)		(0.0282)
Education level				
Illiterature (Reference)				
Primary	-0.933***	-0.930***	-0.576***	-0.585***
	(0.2370)	(0.2370)	(0.2048)	(0.2047)
Junior	-1.572***	-1.572***	-0.978**	-1.016***
	(0.3141)	(0.3141)	(0.3881)	(0.3880)
Senior and above	-1.857***	-1.854***	-1.742***	-1.756***
	(0.4044)	(0.4046)	(0.5624)	(0.5620)
Log expenditure *per capita*	-0.224**	-0.225**	-0.092	-0.097
	(0.1043)	(0.1044)	(0.1020)	(0.1020)
Married	-0.332	-0.334	-0.049	-0.058
	(0.2542)	(0.2543)	(0.2045)	(0.2044)
Urban	-0.809**	-0.813**	-1.049***	-1.070***
	(0.3513)	(0.3514)	(0.3182)	(0.3181)
Han	-0.167	-0.169	0.634	0.580
	(0.6587)	(0.6573)	(0.5864)	(0.5810)
Urban Area before 16 year-old	-0.382	-0.382	-0.384	-0.411
	(0.4021)	(0.4022)	(0.3903)	(0.3902)
Childhood health poor	0.041	0.045	0.520*	0.534*
	(0.3546)	(0.3547)	(0.2945)	(0.2943)
Father's literate	0.085	0.084	0.074	0.064
	(0.2023)	(0.2023)	(0.2148)	(0.2147)
Mother's literate	-0.064	-0.063	0.118	0.135
	(0.4056)	(0.4057)	(0.4708)	(0.4710)
Father's dead before 18	0.201	0.200	0.427	0.451
	(0.2652)	(0.2653)	(0.2908)	(0.2907)
Mother's death before 18	0.456	0.452	0.192	0.178
	(0.3286)	(0.3287)	(0.3773)	(0.3771)
Age groups				
60 - 64 (Reference)				
65 - 69	0.763***	0.767***	1.053***	1.072***
	(0.2155)	(0.2156)	(0.2168)	(0.2167)
70 - 74	0.872***	0.874***	1.620***	1.622***
	(0.2419)	(0.2420)	(0.2501)	(0.2499)
75 - 79	1.598***	1.604***	3.155***	3.186***
	(0.2949)	(0.2951)	(0.3043)	(0.3044)
80 - 84	2.425***	2.429***	3.268***	3.296***
	(0.4256)	(0.4257)	(0.4123)	(0.4121)
85 +	3.111***	3.115***	5.656***	5.663***
	(0.7163)	(0.7164)	(0.5819)	(0.5814)
Constant	2.857	1.486	2.287	-4.689
	(3.1140)	(5.5596)	(2.1502)	(4.8074)
Observations	2,940	2,940	2,928	2,928
R-squared	0.276	0.276	0.283	0.284
Birth province dummies	Yes	Yes	Yes	Yes
Current county dummies	Yes	Yes	Yes	Yes
Wald tests				
Adult SES variables	55.654	55.782	34.485	35.963
P value	[0.000]	[0.000]	[0.000]	[0.000]
Age category dummies	62.901	63.157	187.820	190.221
P value	[0.000]	[0.000]	[0.000]	[0.000]
Childhood SES variables	7.467	7.387	10.481	10.937
P value	[0.760]	[0.766]	[0.488]	[0.448]
Birth province dummies	32.910	32.891	39.482	40.291
P value	[0.035]	[0.034]	[0.006]	[0.005]
Current county dummies	448.936	447.041	374.505	365.708
P value	[0.000]	[0.000]	[0.000]	[0.000]

Note: Adjusted Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Missing dummies are added if available. In Wald tests, adult SES variables include urban, married, education levels and income per capita; childhood SES variables include living in urban area before 16 year-old, childhood health status, parents' education, parents' death before 18 years old.

Table 4.1: Height Shrinkage, Pre-shrinkage Height and Cognitive Abilities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable		TICS (0 - 10)			Words recall (0 - 10)			Draw a picture (0 - 1)	
Panel A: Male Sample									
Measured height	0.0360***			0.0182***			0.0050***		
	(0.00690)			(0.00491)			(0.00132)		
Pre-shrinkage height		0.0309***	0.0313***		0.0106	0.0109		0.0019	0.0020
		(0.00845)	(0.00842)		(0.00625)	(0.00624)		(0.00158)	(0.00158)
Height shrinkage			-0.0400***			-0.0244***			-0.0074***
			(0.00793)			(0.00593)			(0.00148)
Obeservations	2,927	2,927	2,927	2,707	2,707	2,707	2,927	2,927	2,927
R-square	0.308	0.304	0.308	0.187	0.183	0.187	0.199	0.195	0.200
Wald tests									
Adult SES variables		807.481	753.868		332.988	301.605		497.610	457.611
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Age category dummies		93.486	80.272		168.372	145.235		60.546	48.286
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Childhood SES variables		60.839	61.088		39.145	38.810		27.090	26.919
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.004]	[0.004]
Birth province dummies		23.453	21.744		27.866	26.266		11.643	10.173
P value		[0.267]	[0.354]		[0.112]	[0.156]		[0.928]	[0.964]
Current county dummies		298.559	287.286		325.121	322.363		379.441	376.435
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Panel B: Female sample									
Measured height	0.0446***			0.0143***			0.0046***		
	(0.00807)			(0.00542)			(0.00135)		
Pre-shrinkage height		0.0382***	0.0403***		0.0092	0.0100		0.0052**	0.0054***
		(0.00952)	(0.00949)		(0.00664)	(0.00665)		(0.00164)	(0.00164)
Height shrinkage			-0.0477***			-0.0174**			-0.0040**
			(0.0086)			(0.00597)			(0.00147)
Obeservations	2,907	2,907	2,907	2,612	2,612	2,612	2,907	2,907	2,907
R-square	0.332	0.327	0.332	0.208	0.206	0.208	0.223	0.221	0.223
Wald tests									
Adult SES variables		1025.139	965.837		369.093	347.462		652.094	617.288
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Age category dummies		131.381	96.672		165.509	135.017		61.789	43.737
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Childhood SES variables		53.047	53.702		40.338	40.371		30.436	30.403
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.001]	[0.001]
Birth province dummies		42.458	40.754		34.007	32.854		42.207	39.123
P value		[0.003]	[0.004]		[0.026]	[0.035]		[0.003]	[0.006]
Current county dummies		389.944	384.706		439.203	437.663		481.308	472.446
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
County dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Data source is CHARLS 2011. In Columns (1), (4) and (7), OLS robust standard errors are in parenthesis. In other columns, adjusted standard errors are in parenthesis. All regressions include adult SES variables, age category dummies, childhood SES variables, birth province dummies and current county dummies. Missing dummies are added, if available. In Wald tests, adult SES variables include urban, married, education levels and log expenditure per capita; childhood SES variables include living in urban area before 16 year-old, childhood health status, parents' education, parents' death before 18 years old.

Table 4.2: Height Shrinkage, Pre-shrinkage Height and Biomarkers

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Dependent variable		Hypertension			Lung capacity			Grip strength			Balance			Walk time	
Panel A: Male Sample															
Measured height	0.0007			2.7220***			0.3593***			-0.0010			-0.0138**		
	(0.00156)			(0.31405)			(0.02342)			(0.00134)			(0.00581)		
Pre-shrinkage height		-0.0009	-0.0009		2.3068***	2.3666***		0.3452***	0.3498***		-0.0014	-0.0014		-0.0117	-0.0118
		(0.00191)	(0.00191)		(0.4111)	(0.40480)		(0.03240)	(0.03096)		(0.00160)	(0.00156)		(0.00853)	(0.00852)
Height shrinkage			-0.0021			-3.0116***			-0.3673***			0.0006			0.0155*
			(0.00180)			(0.37891)			(0.02932)			(0.00149)			(0.00789)
Obeservations	2,927	2,927	2,927	2,786	2,786	2,786	2,890	2,890	2,890	2,839	2,839	2,839	2,771	2,771	2,771
R-square	0.034	0.034	0.034	0.175	0.159	0.175	0.261	0.224	0.261	0.047	0.046	0.047	0.094	0.092	0.094
Wald tests															
Adult SES variables		28.211	28.218		100.576	73.626		164.605	111.211		23.403	23.129		35.421	32.186
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.001]	[0.001]		[0.000]	[0.000]
Age category dummies		94.192	92.443		437.784	367.951		690.391	554.353		93.132	89.712		114.049	105.402
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Childhood SES variables		20.520	20.604		32.773	31.860		21.884	20.854		36.836	36.760		4.850	4.596
P value		[0.039]	[0.038]		[0.001]	[0.001]		[0.025]	[0.035]		[0.000]	[0.000]		[0.938]	[0.949]
Birth province dummies		23.612	23.492		58.801	61.726		60.492	63.626		19.647	19.536		27.330	27.181
P value		[0.251]	[0.265]		[0.000]	[0.000]		[0.000]	[0.000]		[0.480]	[0.487]		[0.126]	[0.130]
Current county dummies		222.455	222.168		710.432	742.012		664.279	745.753		320.599	319.910		930.769	935.045
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Panel B: Female sample															
Measured height	-0.0005			1.7259***			0.2211***			-0.0010			-0.0152*		
	(0.00163)			(0.23309)			(0.02030)			(0.00163)			(0.00818)		
Pre-shrinkage height		0.0012	0.0011		1.7805***	1.8680***		0.2483***	0.2570***		-0.0013	-0.0013		-0.0189	-0.0193
		(0.00192)	(0.00192)		(0.28813)	(0.28583)		(0.02581)	(0.02503)		(0.00182)	(0.00183)		(0.01235)	(0.01235)
Height shrinkage			0.0016			-1.6173***			-0.1954***			0.0007			0.0122
			(0.00173)			(0.26376)			(0.02253)			(0.00167)			(0.01063)
Obeservations	2,914	2,914	2,914	2,666	2,666	2,666	2,840	2,840	2,840	2,762	2,762	2,762	2,706	2,706	2,706
R-square	0.045	0.045	0.045	0.153	0.143	0.153	0.184	0.168	0.185	0.054	0.054	0.054	0.106	0.105	0.106
Wald tests															
Adult SES variables		43.108	41.406		115.130	95.203		151.373	113.936		30.134	28.395		14.680	13.618
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.023]	[0.034]
Age category dummies		135.474	116.997		275.751	202.839		377.125	248.273		127.133	115.106		154.043	139.200
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Childhood SES variables		19.210	18.656		14.270	13.348		23.499	23.302		10.471	10.339		19.098	19.327
P value		[0.057]	[0.067]		[0.218]	[0.271]		[0.015]	[0.016]		[0.488]	[0.500]		[0.056]	[0.055]
Birth province dummies		47.046	47.545		63.897	57.061		123.892	133.308		20.951	21.240		28.443	28.809
P value		[0.001]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.400]	[0.383]		[0.099]	[0.092]
Current county dummies		221.102	222.364		1256.872	1277.526		1193.134	1275.274		354.754	355.244		706.968	706.783
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
County dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Data source is CHARLS 2011. In Columns (1), (4), (7),(10) and (13), OLS robust standard errors are in parenthesis. In other columns, adjusted standard errors are in parenthesis. All regressions include adult SES variables, age category dummies, childhood SES variables, birth province dummies and current county dummies. Missing dummies are added, if available. In Wald tests, adult SES variables include urban, married, education levels and log expenditure per capita; childhood SES variables include living in urban area before 16 year-old, childhood health status, parents' education, parents' death before 18 years old.

Table 4.3: Height shrinkage, Pre-shrinkage height and Health

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Dependent variable	Poor health (0-1)			Physical Function			ADLs (0 - 6)			IADLs (0 - 5)			CESD (0 - 30)			Life expectation poor		
Panel A: Male Sample																		
Measured height	-0.0017			-0.0048			-0.0017			-0.0038			-0.0438**			-0.0023		
	(0.00143)			(0.00444)			(0.00306)			(0.00331)			(0.01854)			(0.00152)		
Pre-shrinkage height		0.0010	0.0010		0.0097	0.0095		0.0020	0.0020		-0.0006	-0.0007		-0.0305	-0.0314		-0.0005	-0.0006
		(0.00170)	(0.00170)		(0.00508)	(0.00508)		(0.00342)	(0.00343)		(0.00369)	(0.00369)		(0.02282)	(0.02280)		(0.00182)	(0.00182)
Height shrinkage			0.0039**			0.0168***			0.0047			0.0064			0.0541**			0.0037*
			(0.00160)			(0.00481)			(0.00321)			(0.00347)			(0.0215)			(0.00172)
Obeservations	2,939	2,939	2,939	2,728	2,728	2,728	2,917	2,917	2,917	2,923	2,923	2,923	2,762	2,762	2,762	2,588	2,588	2,588
R-square	0.027	0.027	0.028	0.055	0.055	0.058	0.040	0.040	0.040	0.077	0.076	0.077	0.046	0.044	0.046	0.079	0.078	0.079
Wald tests																		
Adult SES variables		56.922	50.477		78.071	67.826		26.294	23.093		55.896	51.114		113.863	103.832		44.367	40.439
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.001]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Age category dummies		14.130	10.836		97.058	81.669		93.867	83.285		161.290	149.749		9.389	7.485		104.208	95.039
P value		[0.015]	[0.054]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.095]	[0.187]		[0.000]	[0.125]
Childhood SES variables		18.690	17.731		9.607	8.830		14.057	14.572		14.298	14.081		12.912	12.397		9.371	9.284
P value		[0.067]	[0.088]		[0.566]	[0.638]		[0.230]	[0.203]		[0.217]	[0.361]		[0.299]	[0.609]		[0.537]	[0.596]
Birth province dummies		17.630	18.092		12.175	12.644		15.999	16.141		18.275	18.460		23.351	23.503		26.513	26.756
P value		[0.612]	[0.581]		[0.910]	[0.892]		[0.717]	[0.707]		[0.569]	[0.311]		[0.272]	[0.264]		[0.151]	[0.142]
Current county dummies		193.464	191.734		243.237	247.293		205.035	206.660		234.033	236.328		336.551	335.082		281.223	279.643
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
Panel B: Female sample																		
Measured height	0.0009			-0.0037			-0.0034			-0.0062			-0.0031			-0.0006		
	(0.00159)			(0.00567)			(0.00372)			(0.00404)			(0.02250)			(0.00170)		
Pre-shrinkage height		0.0036	0.0036		0.0145*	0.0137		0.0104*	0.0097*		0.0124**	0.0115*		0.0356	0.0337		0.0036	0.0034
		(0.00183)	(0.00184)		(0.00611)	(0.00611)		(0.00393)	(0.00394)		(0.00430)	(0.00431)		(0.02580)	(0.02585)		(0.00197)	(0.00197)
Height shrinkage			0.0010			0.0165**			0.0129***			0.0190***			0.0302			0.0035
			(0.00165)			(0.0056)			(0.00354)			(0.00386)			(0.02351)			(0.00177)
Obeservations	2,926	2,926	2,926	2,493	2,493	2,493	2,899	2,899	2,899	2,905	2,905	2,905	2,663	2,663	2,663	2,444	2,444	2,444
R-square	0.029	0.029	0.030	0.051	0.052	0.054	0.046	0.046	0.049	0.085	0.086	0.090	0.042	0.043	0.043	0.065	0.066	0.067
Wald tests																		
Adult SES variables		16.375	14.366		33.936	27.951		28.839	23.587		49.187	38.845		56.350	52.018		21.638	19.225
P value		[0.012]	[0.026]		[0.000]	[0.000]		[0.000]	[0.001]		[0.000]	[0.000]		[0.000]	[0.000]		[0.001]	[0.004]
Age category dummies		23.351	18.747		79.741	60.644		95.268	69.816		189.583	142.781		6.744	4.282		82.793	70.197
P value		[0.000]	[0.002]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.240]	[0.510]		[0.000]	[0.000]
Childhood SES variables		30.597	29.913		42.269	40.246		15.557	14.268		33.087	31.904		31.338	30.454		25.119	24.470
P value		[0.001]	[0.000]		[0.000]	[0.000]		[0.158]	[0.218]		[0.001]	[0.001]		[0.001]	[0.001]		[0.009]	[0.010]
Birth province dummies		31.608	31.070		22.829	22.782		18.201	18.355		34.344	32.951		21.942	21.873		30.080	30.350
P value		[0.047]	[0.054]		[0.263]	[0.300]		[0.570]	[0.564]		[0.240]	[0.341]		[0.343]	[0.347]		[0.068]	[0.064]
Current county dummies		245.738	246.612		332.429	335.726		321.363	326.842		291.425	300.903		427.584	427.024		291.672	290.681
P value		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
County dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Data source is CHARLS 2011. In Columns (1), (4), (7), (10), (13) and (16), OLS robust standard errors are in parenthesis. In other columns, adjusted standard errors are in parenthesis. All regressions include adult SES variables, age category dummies, childhood SES variables, birth province dummies and current county dummies. Missing dummies are added, if available. In Wald tests, adult SES variables include urban, married, education levels and log expenditure per capita; childhood SES variables include living in urban area before 16 year-old, childhood health status, parents' education, parents' death before 18 years old.

Appendix Table 1: Height Comparison with CHNS 1991

Age in 2011	CHNS 1991				CHARLS 2011					Differences	
	MH	SD	# Obs	Age in 1991	MH	SD	PH	SD	# Obs.	MH 2011 - MH 1991	PH 2011 - MH 1991
Panel A: Male sample											
60	165.64	5.67	106	40	164.02	6.58	166.04	5.05	237	-1.62	0.40
61	166.71	5.82	84	41	164.84	6.15	166.60	4.52	219	-1.87	-0.11
62	165.66	6.39	82	42	162.80	6.28	165.55	3.79	262	-2.86	-0.11
63	165.43	5.61	75	43	163.32	6.15	166.13	4.39	210	-2.12	0.70
64	164.81	7.26	79	44	163.51	6.60	165.57	4.25	215	-1.29	0.77
65	163.76	6.71	98	45	163.29	6.57	165.83	4.35	183	-0.47	2.07
66	164.16	6.40	62	46	162.42	6.40	165.39	4.25	150	-1.73	1.23
67	163.36	5.88	57	47	161.44	7.16	165.24	5.09	156	-1.92	1.88
68	163.94	6.41	59	48	161.74	6.45	165.14	4.04	162	-2.21	1.20
69	163.77	6.45	63	49	160.88	6.56	165.43	4.06	142	-2.89	1.67
Panel B: Female sample											
60	154.60	5.89	104	40	152.75	5.91	154.76	4.24	292	-1.85	0.16
61	153.98	5.90	101	41	152.11	6.00	154.32	3.70	249	-1.86	0.34
62	154.19	4.96	97	42	152.53	6.18	154.89	3.88	239	-1.67	0.70
63	154.03	5.86	89	43	152.12	6.43	155.06	4.40	188	-1.91	1.03
64	155.49	6.03	80	44	152.32	5.92	154.86	4.54	221	-3.16	-0.63
65	152.16	6.19	86	45	151.03	6.52	154.07	4.17	175	-1.13	1.90
66	153.61	5.87	61	46	151.53	6.16	154.40	3.89	152	-2.08	0.79
67	153.28	4.55	58	47	150.41	6.37	154.39	4.47	159	-2.87	1.11
68	153.49	5.38	69	48	149.11	6.21	153.83	3.66	128	-4.39	0.34
69	153.96	6.54	67	49	150.18	5.54	154.05	3.53	129	-3.79	0.08

Note: MH - Measured Height; PH - Pre-shrinkage Height; SD-Standard Deviation. Unit of heights is centimeter.