SI for chapter 16 Anthropometry.

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Grandmother depletion. grandepletion
Old age shrinkage or a smaller previous generation shrinkage

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Average height x age aveht

Average weight x age avwt

UAC x age avuac

Triceps skinfold x age avtric

BMI x age avbmi

16.2. Maternal depletion, a cost of reproduction? An opportunity for helpers? Reserves against desertion?

Adult height remains constant between age 25 and 59 (690 pairs of repeated measures of individuals). As in other populations, adult height is related to parental height. In a three-level multilevel regression of height of the 25 – 59 year old adult Hadza, controlling for gender and age, both mother's average height and father's average height made significant contributions ($b = 0.488$, s.e. 0.098, Wald chi-squared 24.8, $p < .001$) and $b = 0.284$; s.e. 0.082, Wald chi-squared 11.99, $p < .001$) respectively). Including the height of the 88 measured mothers of these adults reduced the sample size to 236 observations (measurement occasions). Mother's measurements were strongly and significantly correlated with the measurements of their daughters of reproductive age.

Anthropologists and numerous public health researchers have investigated what they called "maternal depletion", mainly seen as a loss of fatness or weight between births, especially where births are closely spaced (for example Harrison et al. 1975, Tracer 1991). Reviews include e.g. Dewey & Cohen (2007), Winkvist et al (1992), and recent studies include Nenko & Jasienska (2009) and Miller (2010). The original implication was that women use up bodily resources and lose condition from pregnancy and lactation, and may have insufficient opportunity to replenish themselves before the next pregnancy. (The contradiction to the idea that the energy budget plays an important role in determining when the next pregnancy occurs is seldom discussed).

If there is maternal depletion, women are then expected to show lower nutritional status as parity increases. But loss of weight and fat through the reproductive years appears to have been observed in few populations. Tracer (1991) found that among the Au forager-horticulturalists of lowland Papua New Guinea the sum of skinfolds was negatively associated with parity after controlling for SES, time since last birth, and adoptions. Shell-Duncan & Yung (2004) found that nomadic and small town Rendille women of higher parities had lower BMI and triceps skinfolds, while those in the district capital did not. A modest loss of weight between ages 20 and 40 is apparent among !Kung women in Howell's (2010 fig 3.19).

I looked at the 622 weighings of 218 women aged 19-44, which covers the bulk of the child-bearing years. Although in single level regressions there appeared to be effects of parity, after controlling for age, multilevel regressions show no significant effects of parity on weight, upper arm circumference (UAC), or triceps skinfold. Older women had slightly lower BMI. Age at measurement was a significant predictor ($b -.049$, s.e. .015, wald chi-squared = 10.7, $P < .005$) but parity was not. Hadza women's body mass index (BMI) decreases very slightly with age but not with parity. There were significant residuals for individual women (they differ from each other) and in three level regressions, for their mothers (a woman's adult daughters tend to differ from other women's adult daughters).

Studies of maternal depletion have not specifically addressed potential effects of helpers. Helpers could change their work patterns or residence to reduce a woman's burden. This could remove long term effects of repeated pregnancies and lactations. Perhaps Hadza women lose so little weight during the child - bearing years because they are well buffered by helpers. But the proportion of adult career in a marriage had no effect on weight, BMI, UAC, or triceps skinfolds in multilevel regression. Nor were a woman's measurements related to her husband's nomination scores.

Women whose mother had died tend to be lighter for their height and age than others (controlling for age and parity, BMI: b – 0.570, s.e. 0.249, Wald chi-squared 5.24, p = < .025) in this 20 – 44 year old age segment. The difference was also seen in UAC but not triceps skinfold and was only marginally significant for weight. No striking effect of mother status on the effects of age or parity was seen, and an interaction term was not significant. Women who had lost their mother included those who had lost her during childhood and their adult size probably reflects the result of growing up as an orphan. It is not a demonstration of an effect of helper status on maternal depletion. Mothers who had died left few records so I could not control for their weight in looking for effects of mother's death in this age group. This gives no firm indication of a buffering effect on women of child-bearing age from either husbands or grandmothers.

Compared to populations in which maternal depletion is seen, perhaps Hadza women are better able to influence how soon the next child arrives. They certainly have no restrictions on their access to food, other than their own time and energy. But the issue of helpers and maternal depletion may repay more careful study in larger samples that show clear evidence for depletion. Hiernaux & Hartono (1980) suggested that compared to anthropometric studies of other African women, Hadza women seemed to be at less of a disadvantage when their skinfold measurements were compared to those of men. If Hiernaux is right about the nutritional status of Hadza women, we should see little sign of maternal depletion. But despite my failure to convincingly show maternal depletion, it would be easy to believe that the fatness of young Hadza women is accumulated in order to be spent producing the first few babies faster than would otherwise be possible.

Late middle age: do hardworking grandmothers lose weight?

Kaplan et al (1994) argue that post-reproductive adults of both sexes subsidize the reproduction of younger adults. Howell (2010: Fig 3.22, Fig 3.24) shows a quite sharp decrease in weight and BMI of older !Kung of both sexes from their mid 40s onward. !Kung women lose some 10 kg in weight from their 40s to their mid 70s. Howell's investigation of energy balance suggests that these older people work themselves into a state close to WHO "moderate thinness" helping to feed their younger kin and others.

But among Hadza aged 45-65 I find very small or negligible decreases. I found small significant decreases in women's height and weight but no change in BMI. I have not examined grandparent weight change in relation to number of small grandchildren or presence or absence of their father. Sherry & Marlowe (2007) also report no age decline in BMI but using impedance measures of body fat they show that the oldest women had a lower percentage body fat than younger women. Below I show that the smaller size of the very old represent loss of height and weight. They do not indicate a previous generation of smaller Hadza, as we can also see by comparison with the measurements by Hiernaux & Hartono (1980).

Older Hadza women show wild fluctuations in triceps skinfold. "Floppy arms" of old age are not escaped by the hardy hunter-gatherer lifestyle. In some people they appear to be the deflated skinny remnant of the turgid store in the arms of young women. In others they appear more substantial. One could speculate that they comprise a rapidly filled and depleted storage organ for hardworking Hadza grandmothers.

Table. Is there Grandparent depletion? Among 45 to 65 year old Hadza men and women, multilevel regression shows that measurements taken at greater ages show very slightly lower height and weight but age accounts for very little of the variance in the data compared to individual differences. On average, a woman loses just 3.5 kg in the 20 years.

Women 45-65	beta	s.e.	Wald stat / p	Cases / occasions
Height	-.064	.017	14.2 / <.001	71 / 190
Weight	-.174	.047	13.70 / <.001	71 / 190
UAC	-.069	.029	5.66 / <.025	71 / 190
Triceps	.144	.077	3.50 / <.10	68 / 176
BMI	-.041	.020	4.2 / <.05	71 / 190

Men 45-65	beta	s.e.	Wald stat / p	Cases / occasions
Height	-.052	.017	9.36 / <.005	71 / 161
Weight	-.210	.053	15.70 / <.001	70 / 153
UAC	-.084	.022	14.58 / <.001	71 / 161
Triceps	-.005	.018	9.34 / <.005	65 / 142
BMI	-.066	.019	12.07 / <.001	69 / 151

The elderly. Do old people shrink, or are they a record of the past?

Both Marlowe's graphs and my plots of average height and weight, and my plots of each data point appear to show old people as very slightly shorter and lighter than middle aged and younger adults. Sherry & Marlowe (2007) remark that their 11 women aged 75 or more lost body fat, dropping to the level of males. Do old Hadza shrink, like old people in other populations? Other widely observed aging patterns, such as increases in blood pressure and cholesterol levels were not found among Hadza (Barnicott, Bennett, Woodburn et al.). Is loss of stature in the elderly also a "disease of civilization"? Alternatively, perhaps the elderly Hadza of today represent the typical height and weight of a previous generation of Hadza. The secular data suggest not. Another possibility is that smaller people survive old age better than larger people (the large literature on weight and weight change in elderly N American and European populations suggests that large changes in weight, either increase or decrease, predict earlier death). We can try to separate some of these possibilities with our mixed longitudinal data.

In multilevel regressions on the over 60s (100 individuals, 243 measurement occasions) we can see a decrease in stature with age and plot some of the individual fitted growth trajectories. Age at measurement (after control for gender) is a consistent significant predictor of height (b -.110, s.e. .021, wald chi-squared = 27.4, p = <.001). Over the 15 years of our study, individuals born as much as 15 years apart could be measured passing, say, their 65th birthday. If year of birth is added to the regression model (to control for secular change), age retains its significant effect while year of birth is not significant (b -.140, s.e. .086, wald chi-squared = 2.65, p approximately = .10). Most persuasive, individuals with more than one measurement could be seen to get a little shorter as they aged. A variable comprising a count of each individual's measurement occasions, beginning from the age of 60 was added to the model instead of age. Its beta coefficient was - .320 and with s.e. .053 its p value was <.001.

This analysis shows that old Hadza do get a tiny bit smaller, they are not relics of an era of smaller Hadza. We can also test this by looking at people measured by Lars Smith in 1977 who were still alive and measured between 1985 and 2000. Men and women who were aged over 40 in 1977 (and average ages at weighing during 1990-2000 were 66 and 64 respectively), lost weight and height. Surprisingly men lost more weight than women (5 kg versus 3 kg) but with N of 45 women and 22 men the difference was not significant. Both sexes lost height (women 2.0 cm, men 3.4 cm.) just beyond the 95% confidence limits of our height measurements. Even if we should subtract 1kg from the weight changes due to the change in weighing machines, the data suggest a slight loss of weight among older people. The sample is not big enough to look at the very oldest age groups where the greatest loss of size would be expected.

16.3. Methods. Appendix on methods and tests.

Weight, height, upper arm circumference, and triceps skinfolds of a large number of Hadza have been accumulated since Hawkes & O'Connell' s intensive fieldwork in 1985-86. Lars Smith made available his weight and height data from 1977-78. We know the ages of most children born since 1984 to the nearest year or better, and those born in 1976-78 to nearly the same accuracy.

One thousand individuals were measured and 754 of them measured more than once, a few were measured in 5 or more different field seasons. There was a total of 3194 person - measurement occasions. Our data are thus “mixed longitudinal”. Multilevel analysis is used to deal with some of the problems associated with mixed longitudinal samples. Of the 1000 people measured, 646 were under age 25, and 346 over 25 and there were 8 cases with unrecorded age.

N observations	N subjects	N subjects under 25 (<25)
1	246	202
2	206	130
3	160	104
4	149	100
5	115	57
6	66	37
7	34	16
8	21	7
9	3	1

Equipment:

Weighing machines.

Hiernaux & Hartono say “Techniques of measuring followed IBP recommendations (Tanner, Hiernaux and Jarman 1969)”. A later publication (Weiner & Lourie 1981) based on the IBP handbook recommends a portable field survey scale (beam scale). Since, after the desertion of Yaeda and Munguli, many Hadza camps could be reached on foot only, Lars Smith used a portable bathroom scale which he and our group calibrated independently. One of the samples of calibration weighings shows Lars' scales reading nearly half a kg higher in the 30 – 50 kg range but accurate above and below this. We used digital readout, load cell weighers, in 1985-86 a bulky one made by Weylux and subsequently an extremely portable one by Tanita. Other calibrations suggest good matches between our Weylux and Tanita load cell weighers and the Soehne Model 7701 load cell weigher used by Sellen (2000 and elsewhere). There were also excellent agreements between our weighers and the spring weighers used to weigh food and strength. An important limitation of the Tanita load cell weigher is that it could not read higher than 60kg. There were two Hadza women who quite often weighed more than the scale could handle.

Two weighers were used, one used from 1985 to 1989 was a Weylux electronic load cell weigher, powered from our car battery via an inverter. This was large, complicated to use, and heavy. The second was a Tanita load cell weigher purchased in July 1990, powered by C-cell batteries (by then readily available even in quite small towns). This was very compact, like a bathroom scale, and easily carried to camps that could not be reached by car. On each machine weight was shown instantly on an LED screen ("digital readout") and written down by the researcher after the field assistant had written down the name of the subject and his or her parents. Smith's 1977 weighings were obtained with a bathroom scale, with a dial display. Its display is much more difficult to read than the numerical displays of our later weighers which displayed weight to .01 kg.

We calibrated weighers by weighing a series of objects ranging from about 3 kg to 60 kg or more on each weigher. Our Tanita load cell weigher has been calibrated against the Weylux and against Smith's "bathroom scale" weigher, and a Soehne load cell weigher used by Daniel Sellen of UC Davis in studies of the neighboring Datoga. The agreement between the three load cell weighers was excellent. There was one weighing that showed a difference of .05 kg between the Tanita and Weylux, out of a series of weighings from 3 to 60 kg. There was one difference of 0.1 kg between the Soehne and Tanita in a series from 4.7 kg to 58 kg.

Smith's bathroom scale was compared with two hanging spring weighers. The bathroom scale weighed low in the middle range (4 – 25 kg) and seems to have weighed high at higher weights. It is difficult to read the dial on bathroom scales, "digital" readouts are a great improvement.

Stature (height) was measured using a portable stadiometer. The vertical shafts were made of square section aluminum, the headpiece was plastic. The vertical shafts slotted onto a square steel stub welded to a heavy steel platform with a thin rubber mat on its surface. The platform (essential on soft uneven ground) was too heavy to easily carry to camps that were not accessible by car. A well built box that could be filled with rocks or sand to make it stable might be a more portable improvement. The scale was marked in cm and mm. Heights were recorded in cm to one decimal place (ie to nearest mm). Flexibility in the attachment of the head piece to the vertical shaft, as well as flexibility in the subjects, rendered the millimeter resolution unrealistic.

Upper arm circumference was measured with a steel tape marked in cm and mm. In 2000 this was lost and I used a tape marked in inches. The measurements were converted at cm = 2.540 x inches. Triceps skinfolds were measured with a Harpenden skinfold caliper (manufacturer: Holtain, supplier; Camden Instruments). This exerts even pressure at all widths and does not pinch.

Measuring triceps skinfolds.

The mean skinfold of adult Hadza men is 4.7 mm (Figure 6). Adult Hadza men have almost no subcutaneous fat. Trying to use the skinfold calipers on adult Hadza men is quite tricky, there is so little to grasp. When their arm is relaxed (they often started out with the belief that we want to measure it tensed), one can pinch up some skin and the caliper end-piece is just small enough to grasp this. The usual measurement is between 4 and 5 mm and it feels as if this is simply the thickness of two layers of skin. Using the calipers on young women is a complete contrast. Here a common problem is that the subcutaneous fat is so turgid that you cannot raise a fold to get the calipers around, and just occasionally a fold is too wide for the calipers to grasp. Some of our higher skinfold measurements on women are very inaccurate and are under-estimates. Although triceps skinfold remains low in adult men, using impedence methods, Sherry & Marlowe (2007) showed that Hadza men were able to increase body fat during the ages 30-45, presumably storing it somewhere other than subcutaneously.

Procedure.

The procedure started by Smith in 1977 and developed into routine by O'Connell and Hawkes during 1985-86 was followed closely. Hadza expected us to weigh and measure them as soon as we arrived in a camp. The first task was to clear and level a patch of ground about 2 x 2 meters to remove thorns, rocks and stabilize the equipment. The equipment was set up and was leveled by spirit level.

Hadza waiting to be measured were asked to remove their shoes (if they were wearing any), their knife, and jacket or second shuka, The person was asked for his/her name by our Hadza field assistant who entered this in the record book next to the measurements. They were guided to stand on the weigher platform, then when weight had been written down to move to the stadiometer platform. After height was measured and recorded I measured upper arm circumference and triceps skinfold. I then gave S a large cup full of maize meal as payment. By popular request, anthropometry was started within minutes of arrival at a camp. People who returned later from the bush were measured when they arrived and asked to be measured.

Babies were weighed while held by their mother, and their weight obtained by subtracting mother’s weight. Our weigher could not weigh more than 60 kg so sometimes a smaller caretaker was asked to hold the baby. While the baby was in the caretaker’s arms I measured upper-arm circumference and triceps skinfold. No attempt was made to collect stature or supine length on babies. Toddlers, those who could stand, by definition, stood on the stadiometer platform but sometimes were too short for the equipment. Thus stature is missing from the records of many of the younger children. A few small children seemed intimidated by the procedure, and parents’ efforts to push them into being measured were resisted by giving the baby's payment "for trying". This procedure met with no objections, it seemed to be widely approved.

Measurements were always conducted under pressure of time. Hadza were eager to get their payment, a substantial sized mug of maize flour. Measurements were usually started within minutes of our arrival in a camp, often after a difficult and tiring journey. Distances were usually short but packing up and loading the car to leave the last camp is time consuming and tiring, and the driving was sometimes difficult, punctures not unusual. In the event of a puncture always ask your passengers and helpers to start a fire and make some tea before you begin to change the wheel, it keeps them occupied, and removes any sense of emergency. Carry 2 spare wheels. Measurements were made and recorded by me. Gudo Mahiya wrote the names and parentage of each subject as they stepped up to be measured, handed the notebook to me and I entered the measurements as I made them. ID numbers were determined and entered later. This was sometimes very difficult and a few mistaken identities are possible. Some records had to be discarded because identity was uncertain.

The stadiometer platform was leveled at each site using a hoe and a spirit level. Re-leveling was seldom performed during a measurement session. If the platform became unlevel during a session some individuals would be standing not parallel to the vertical shafts which would subtract minutely from their apparent height. If the platform rocked, the subjects were quite badly un-nerved. If dust and grit built up on the platform it would minutely increase someone's apparent height, grit building up around the stub would be more important. The platform was brushed clean between almost every person. The stub was not cleaned during a session. Wear in the joints of aluminum vertical shafts could lower the whole measuring device. We did not notice significant wear.

Much more significant was variation in the subjects' readiness to stand fully erect. We did not routinely hold the subject's head and lift nor did we have anyone to check that people's heels remained firmly on the platform. We did check that everyone removed their shoes before being measured. Most people got the idea of standing fully erect, with shoes off and feet together, a few needed to be shown, or helped by holding their head but this was not routine. These several departures from the laboratory ideal certainly introduced unwanted variation in our measurements. We attempt to estimate roughly how much variation as follows.

Assessing accuracy of height measurements.

Because Hadza move about so much, and we never refused anyone the chance to be measured and receive their "pay", a few people were measured more than once in each field season. We can look at the repeat measurements to evaluate the reliability of our measurements. Height is especially difficult to measure repeatably, so I attend primarily to our measures of height.

In 1999 an unusually large number of people were measured twice, partly because our field season was longer than most, but mainly because an unusual movement took us by surprise. Two camps of people measured near Lake Eyasi on 9th October, had moved back to their normal region by 30th of October. Sixty-nine people were measured twice. Thirty - nine of them were adults aged 20 or more.

I calculated measures of repeatability of the height measurements. The 39 adults measured twice in 1999 showed an average change of –0.18 cm., i.e. the average height declined by about 2 mm. But some measured taller and others shorter, so the absolute difference gives a stronger indication of fluctuation between measurement occasions. The mean of the absolute (sign removed) differences was 0.7026 cm (7 mm), with sd 1.009. The average height of these 39 men and women was 154.9 cm, so the mean difference was .0045 of their height (0.45 %). The coefficient of variation (within subject SD / mean was .0065, or 0.65%. The intra-class correlation coefficient (ICC) (as described in Machin, Campbell & Walters (2007) also seemed to be an appropriate measure of repeatability. This is between subject variance divided by total variance (within subject variance plus between subject variance). Our data showed an ICC of 0.9987 for the adults measured twice in 1999.

The corresponding figures for the 68 cases including children were -0.24 cm difference between first and second measurement, 0.7471 mean absolute difference with sd 1.039, CV 0.007 (0.7%), and ICC 0.9991.

To form a second sample, I assumed that adults aged 25 –60 neither gain nor lose height over a span of a year or two, and examine the matches between successive measurements of their height. This gives us 690 pairs of measurements, a much larger sample, separated by periods of more than a year. The next figure below plots the data, and the line fit by a regression of height at time 2 on height at time 1. The outlier at 154cm x 148cm was discarded from the data as a case of mistaken identity (erroneous attribution of ID number). The mean difference between the first and second height was 0.0007 cm. with sd 0.9482. The inter-quartile range for the differences was between – 0.6 and + 0.6 cm. The 95% CI is +- 1.86cm. Since we are convinced that adults do not grow taller or shorter, the absolute differences between the 2 measurement occasions are more important for assessing repeatability of our measurements. The mean absolute difference was 0.7059 cm and its quartile range was from 0.200 to 1.000, with sd 0.6325. The average height was 155.22 cm, so the average change was 0.0045 of the height, or 0.45%. Its sd was 0.6325, so the coefficient of variation was 0.41%. ICC was calculated to be 0.9940, which is very high.

The conditions under which our measurements were taken are probably similar to those of many other studies of subsistence societies, they were certainly no more difficult than the conditions under which Sellen measured Datoga children. I have seen no other assessments of the repeatability of such measurements under non-village field conditions (no houses or other substantial shelter, no floor, no artificial light or electrical power, minimal assistance, no local records of age or identity, subjects who never attended school or clinic). Perhaps our data can stand in as a representation of the likely accuracy of measurements collected under such conditions. If we compare these results with studies of accuracy in a variety of settings we may get a picture of the quality of our measurement technique.

Auxologists have been interested in accuracy for two rather different reasons: 1) to reach accuracy that make it possible to study short term growth and factors responsible for individual differences in short-term growth; and 2) to develop economic ways to use growth as a part of mass population health screening.

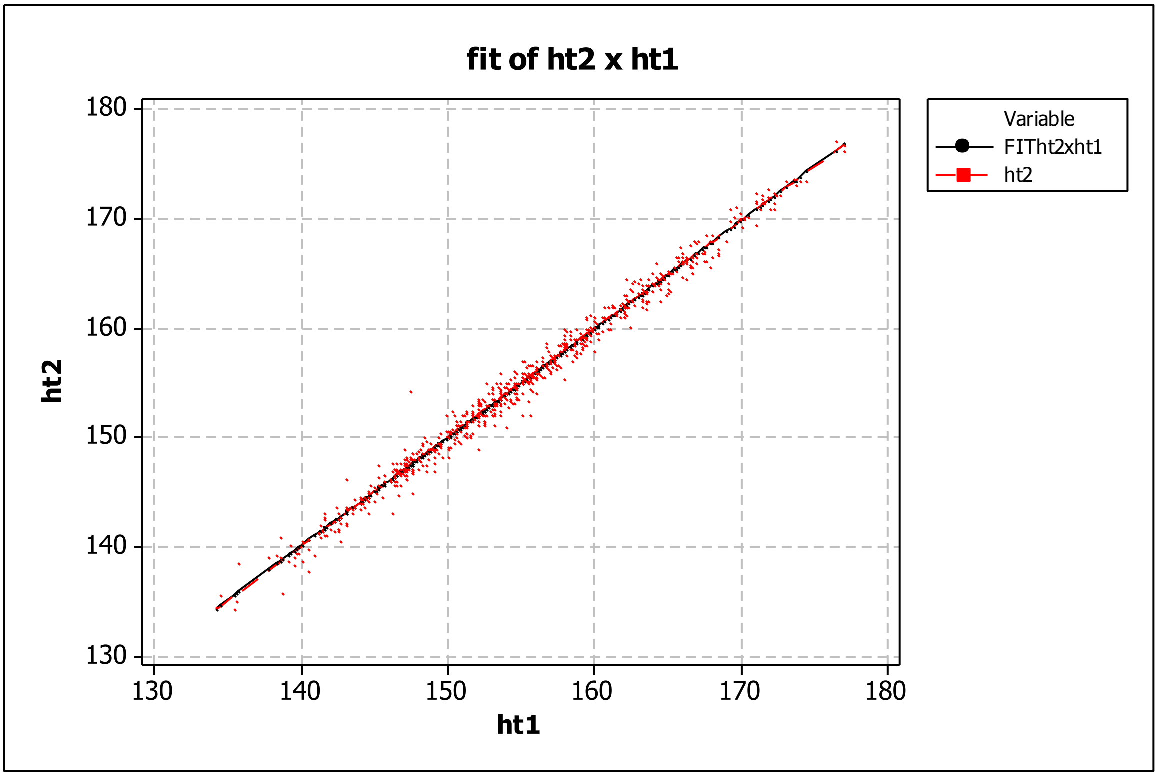
An example of the first direction, Tillman & Clayton (2001) found diurnal variation in two boys measured repeatedly, of as much as 1.44 cm and suggested restricting measurements to between the hours 1800 and 2100. This is completely impracticable in a field environment where darkness falls soon after 1800 and Hyaenas begin to patrol shortly after that. But I am encouraged to see that differences due to diurnal change in a single individual may exceed the size of the average difference between, and inter-quartile range of our repeat measurements.

In an extreme example of the second direction, Lipman, McGinley et al. (2006) compared university Obstetric & Gynecology clinic staff with a research assistant conducting the study. Measurements differed widely, by as much as 18 cm and with a mean difference of 6.4 cm – a difference that in our data would lead me to look for evidence of mistaken identity.

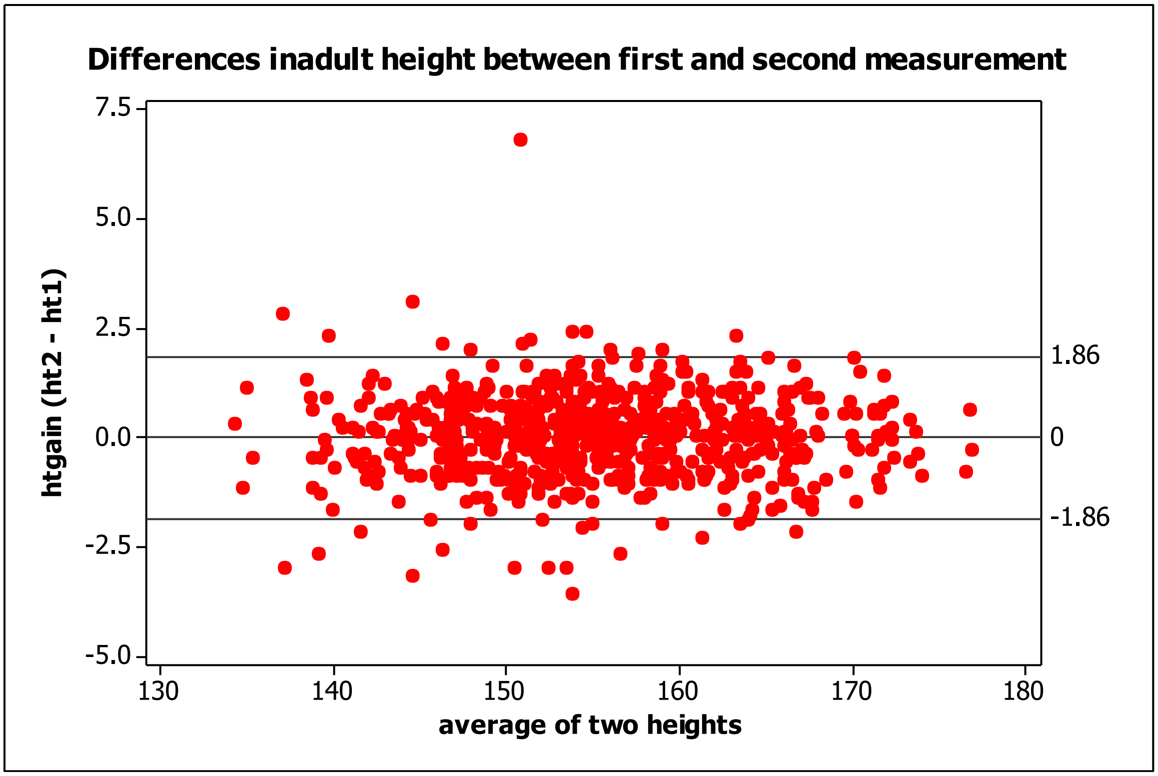
A fairer example of the second direction is that of Ahmed, Yudkin et al (1990) aimed at testing the validity of screening for faltering growth velocity in children aged 3 to 4.5. Measurements by UK health visitors using two kinds of device (wall chart, microtoise) were compared with measurements by an experienced auxologist using a Harpenden stadiometer. The SDs of the health visitors' measurements differed by as little as 0.1 and as much as 1.01 cm from those of the experienced auxologist. The pooled results for the four health visitors showed SDs between .36 and .57 depending on method and child age. These figures are a little lower than the sd that I obtained on repeat measurements of adults. The coefficient of variation (which takes average height of the subjects into account) is very similar to mine. Ahmed et al. warn that the level of error they encountered could have substantial effects on identification of growth faltering in individual children.

A methodological study by Geeta et al. (2009) is more easily compared with the Hadza data. Geeta et al. compare repeat measurements by the same and different trained measurers on a sample of 130 adult office workers aged 18-64 in Malaysia (mean ht 157.2 cm). Examiners showed a mean difference of zero between sample means at the two examinations, close to the 0.0007 cm. of our larger sample. The standard deviation was 0.32 and the coefficient of variation was 0.2%, about half my score. However, these authors suggest "CVs <= 5% generally implied a good method performance". Their ICC were 0.999. The Hadza data do not look substantially less accurate than the Geeta et al data. This may mean that the anthropometric data reported by field anthropologists of subsistence populations are as accurately measured as those reported in larger scale public health studies and may overlap in accuracy with some laboratory or clinic studies.

Fitted regression line and original data points for 690 pairs consecutive height measurements of Hadza aged 25 – 60.



Plot of differences between height (cm) at time 1 and height at time 2 against mean of the two heights. Horizontal lines mark zero difference, and 95% limits (sd * 1.96).



16.3 Weaning.

Biological life history researchers have noted that in cross-species samples of mammals, weaning tends to occur when the infant is one – third of mother's body weight. The proportion is rather lower in Primates, and still lower in humans (Walker et al. 2006, Walker, Gurven, Burger et al. 2008). Subsequent investigation showed that weight of weanling per annum, and weight of neonate p.a. varies with mother's body weight to .75 power. This implies a trade-off between fertility and offspring "quality" (size) that Walker et al (2008) confirm for humans with data from several subsistence societies. These studies propose that growth of the suckling offspring is determined by mother's biological productivity rather than its own, being predicted by mother's size not by offspring size. Some have suggested that weaning age may be expected to reflect both parent – offspring conflict, and mother's trade – off between quality and quantity of offspring. In most mammals, among which weaned offspring rapidly become self – sufficient, the sooner a female weans an offspring, the sooner she can begin to direct her biological productivity toward producing the next offspring. Some have looked at sex differences in weaning age or size in relation to mother's access to resources as tests of the Trivers -Willard hypothesis (Trivers & Willard 1973).

Hadza weaning weight as % adult female weight.

Hadza women's average weights at age 18, 19, 20 were 45.3, 44.3, 47.2. if we take 46 as representing a more likely fit to age 19, (it is also the average for years 19-44) then Hadza children are weaned at 10.3 / 46 = 22.4% of maternal weight at first reproduction.

Fitting child's weight when last suckled.

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Avage is moms ave age at metry while an adult
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Regression with Life Data: wtlastsu versus dadtrb, sex, momwt, avage

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* NOTE * 185 cases were used
* NOTE * 12 cases contained missing values


Response Variable Start: wtlastsu  End: wtfstwn

Censoring Information    Count
Uncensored value             1
Right censored value        80
Interval censored value     44
Left censored value         60

Estimation Method: Maximum Likelihood

Distribution:   Logistic


Regression Table

                     Standard                  95.0% Normal CI
Predictor      Coef     Error     Z       P      Lower    Upper
Intercept   35.4775   17.6771  2.01  0.045   0.830992  70.1240
```

```
dadtrb       6.86878   7.05366  0.97  0.330   -6.95615  20.6937
sex          6.56750   3.63216  1.81  0.071  -0.551394  13.6864
momwt       0.654126  0.331348  1.97  0.048  0.0046959  1.30356
Scale        8.67667   1.05372                 6.83881  11.0084

Log-Likelihood = -83.625
```

Weaning weight is associated with child sex (males heavier) and with mother's weight. The separation of early mammalian growth into two phases, mother powered, and child powered, appears to match the separation made by Karlberg (1987, and Karlberg et al 1987) between infancy and childhood growth. Initially basing the distinction on fitting curves to growth in length, Karlberg points out that the endocrine control of growth appears to differ between these phases. Karlberg's transition appears to relate to the start of Bogin's childhood. Both have been enthusiastically endorsed by Hochberg (Hochberg 2008, 2009, 2010) who links both to various aspects of abnormal growth, and to human origins and evolution.

Carnivory. Psouni et al. (2012) recently argued that humans are not weaned early, when scaled by brain weight, or carnivory. Some comments need to be made. The contribution of carnivory to her model was strongly significant ($p < .0001$) but quite small (3.4% of the variance). Carnivores provision weaned offspring, like humans. Some carnivores have helpers, even to the extent that the helper's own reproduction is suppressed. A category of "post-weaning providers" might give the same result in Psouni's regressions as carnivory and give comparative support to the linkage between helpers and early weaning. Generally speaking, weaning age and weaning weight are related by growth rate, which is related to mother's milk production, which is related to her size. I'm not yet convinced that Psouni's account contradicts existing accounts based on weaning weight. The inclusion of plantigrade walking (10.3% of the variance) as a character among her independent variables is unusual and confirms that we still have much to learn about the determinants of time of weaning in any animal.

Altriciality. Whether ultimately due to carnivory, or to the whole suite of large packet, difficult to acquire savanna foods, the period of "early childhood" is probably much more important for understanding human evolution than the oft quoted "helplessness" or altriciality of human newborns. This idea, initiated by Bolk (1926) and Portmann (1941) when they described human newborns as relatively altricial compared to other apes, has been greatly exaggerated and made into a reason for the long human juvenile period (the time from birth to first reproduction). It may be true that humans crawl slightly later than Apes, but they walk bipedally by around a year old. Do any apes manage their inefficient bipedal walking any earlier? It seems unlikely. The small newborn differences can add only a few months to the juvenile span. Perhaps the view is that humans are developing slowly, and then the differences in capacity at birth could indeed be symptomatic of this. This is different from the usual attribution of elongated lifespan to altriciality. Alticiality (the condition at birth or hatching) is not an explanation for slow growth (if human growth IS slow), or late age at first reproduction. Robson et al. (2006: 31-35) give an excellent review of the altriciality idea.

SI 16.4. Ages 6 – 16.

I ran a 3-level regression of 815 measurements of 335 children of 152 mothers and Hadza fathers. I tested for the best fit to age, for height and for weight in multilevel regression, with intercept random at j (child) and k (mother). Adding age-squared to the model improved the fit significantly and adding age-cubed did not. Thus I used age + age-squared in subsequent models for children in this age range.

Then I added to the best model "nrsch" (the number of occasions seen in school), fathers tribe (Hadza or "Swahili") and "momagebth" (mother's age at the birth of the subject child). Father's tribe was a consistent factor, children with a Swahili father were taller than children with a Hadza father. So I examined a second file from which I removed all children with Swahili fathers, leaving only children with Hadza fathers.

In the file of children with Hadza fathers the best fit of age was age + age-squared. Children who attended school for more years were significantly taller. There was no significant gender difference in height. Children born to older mothers tended to be taller. Children born to taller mothers were significantly taller. Children born to taller fathers were significantly taller. Mother status (dead or alive) had no significant relationship to child height, and no significant interaction with child gender or mother height. Weight is a different story, see below.

<u>School attendance</u>. Fifty three children age 6-17 attended school (most for only a single year) where they receive food, and on average they grew larger than others, as reported above and by Blurton Jones & Marlowe (2002). School attenders contributed 220 out of 898 measurements of this age group. School attenders were taller, heavier, but no different in UAC, triceps skinfold or BMI. Children were about 1 kg heavier and 2.5 cm taller for each year in school. The effect on fatness of some of the girls was especially striking in the field. There is a large and significant statistical effect but when the whole sample of girls are plotted two things are apparent. First, that there are many girls who, even if they stayed in school more than a year, did not gain a striking amount of weight or triceps skinfold. Second, the biggest difference in weight is among the younger girls, aged 11-15. After age 15 girls who do not attend school, or who attend for less than a year, appear to catch up with the weight of their school-attending peers. But a significant effect of the number of years in school remains among the 16-25 year olds. Studies that report beneficial effects of women's schooling on their children should take account of effects on the woman's own size and nutritional status.

Orphans are smaller.

The children who we measured included some orphans, children whose mother had died. Among those aged 6-16 whose fathers were Hadza, 16 girls and 19 boys had lost their mother. There were 436 measurements of girls and 385 of boys with Hadza fathers. Ninety (90) measurements were of children whose mother had died, and 731 of children whose mother was alive. The youngest measurement of an orphan was of a boy at age 3.7, and a girl at 6.7. Younger orphans may have died before we met them. Mother status (alive = 1, dead = 2) at the time of measurement was added to the regression model. In all the regressions mother status had a strongly significant effect. Orphans were lighter for their age. The pattern for weight was very consistent, excluding or including other factors such as school attendance, and when children of non-Hadza fathers were included, father's tribe made no difference to the effect of mother. The effects of being motherless were confirmed in multilevel analysis.

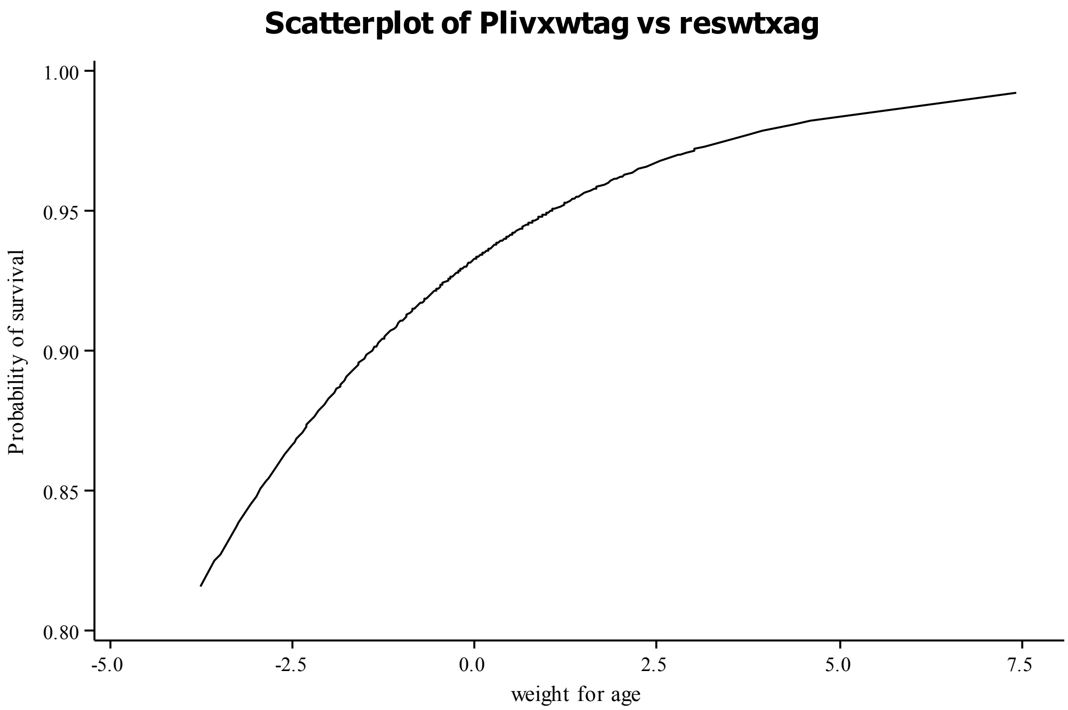
However, if we separate the boys from the girls we find that the effect of losing mother is not statistically significant for boys (table below). Orphans were more likely to be sent to school and to stay there longer (Pearson correlation 0.110 p .002). Since among children who were ever sent to school, boys tended to stay in school for more years than girls, I wondered whether school food might have compensated boys' growth for the loss of mother. In multilevel regression of the male sample weight was predicted by school attendance and not by mother status, perhaps confirming my expectation.

Table. Female orphans tend to be smaller for their age. Results of multilevel regressions testing for effect of mother status (dead or alive). Ages 1 – 17. Table shows beta, standard error, Wald statistic and probability for mother status, controlled for age, age-squared, gender. There were 170 girls, with 434 records, 16 were orphans, with 41 records. Among the 162 boys with 371 measurements 20 individuals were orphans with 50 measurements.

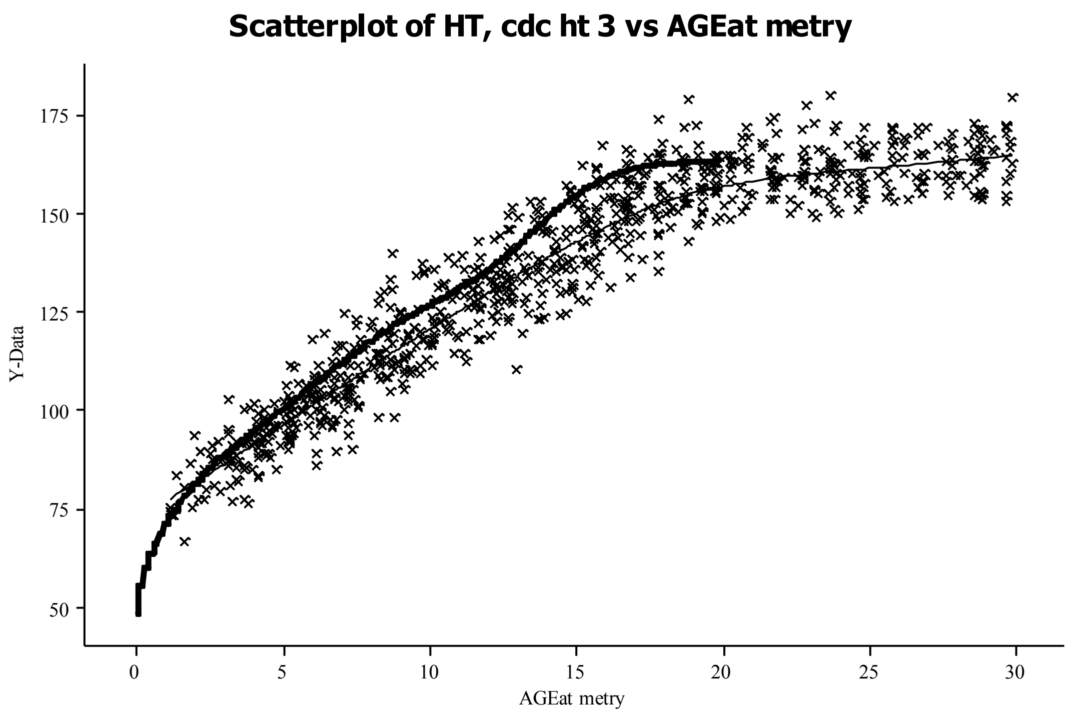
	Boys	s.e.	Wald stat, p	Girls	s.e.	Wald stat, p
Height	b – 1.377	1.236	n.s.	b –1.945	1.383	1.98, n.s.
Weight	b -.568	0.648	n.s.	b –1.971	0.964	4.18, <.05
UAC	b .056	0.226	n.s.	b = -.860	0.352	5.97, <.025
Triceps skinfold	b -.619	0.260	5.62, < .025	b = -1.666	0.538	9.59, < .005
BMI	b -.012	0.247	n.s.	b = -.618	0.372	2.76, <.10

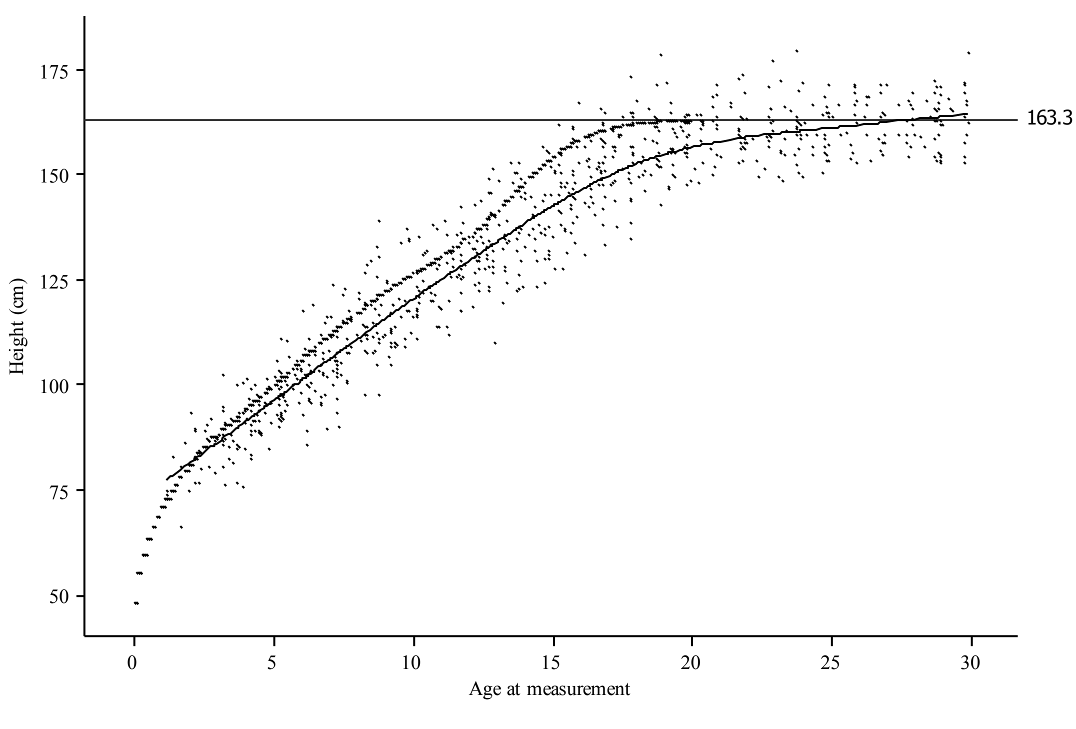
16.5. Diminishing survival returns to weight.

Survival x weight for age among one to five year olds.
23 deaths 315 measurements. Weight for age beta -.3026 p .051 OR 0.74 (.55 – 1.0).



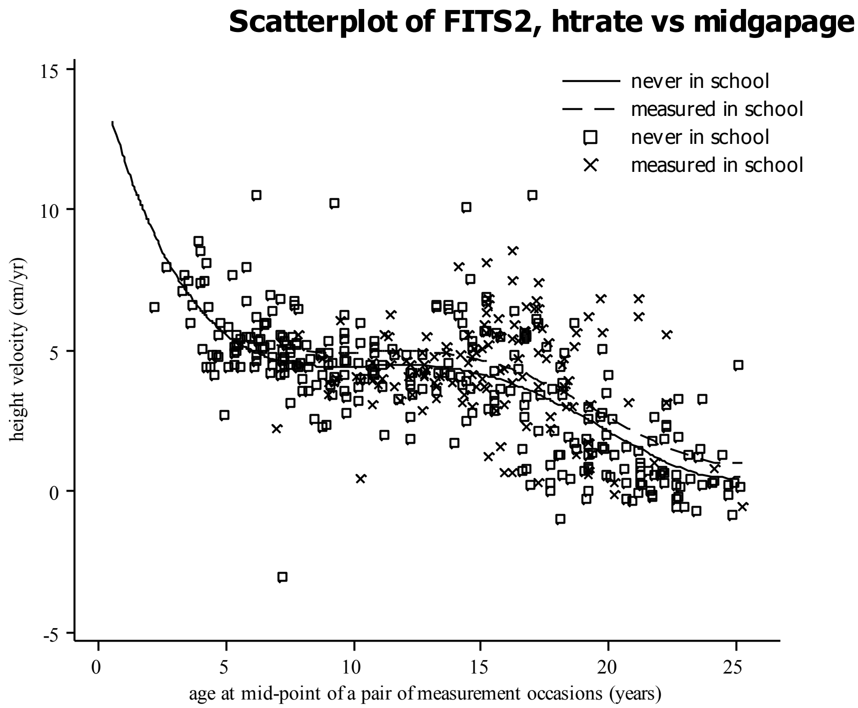
SI 16.6. The African boys pattern? Height (y-axis) x age. Hadza plotted with CDC 3rd percentile, which levels off at 163.3 cm just before age 20. Hadza continue to get taller after age 20. Lowess smooth of the Hadza records reach 163.3 between age 25 and 30. Same as figure in text.





Is there an adolescent growth spurt?

Fit line htrate = midgapage + ^2 + ^3 + ^4 + any school (b = 0.5005, t = 2.57, p = 0.10)
Ever in school: 'x' and broken line
Never school squares and solid line



General description of Hadza growth and adult physique.

Marlowe (2010) showed Lowess smoothed graphs of Hadza height and weight from his observations between 1995 and 2010 which match closely with my data from 1986 to 2000. On the previous page I showed individual data points for Hadza under age 30 plotted alongside the CDC standard third percentiles for height and weight. Height follows an almost linear path from age 2 until 15 with no apparent difference between boys and girls. At around age 15 girls' growth in height begins to slow down, while boys continue until over 20. Hadza boys and girls growth tends to fall just below the CDC standard 3rd percentile for height and weight from around age 5, but they meet the 3rd percentile again in their early 20s. This implies a slightly different trajectory of growth from even the smallest North American children. But a similar trajectory has been reported in several other African populations (Cameron 1991, 1994, Little & Johnson 1987).

Means and sd of average adult Hadza height, weight, upper arm circumference, triceps skinfold, and body Mass Index during 1985 – 2000.

Males 20-85	Mean	sd	min	median	max	N
Aveht2k	160.6	6.21	139.1	160.56	180.0	232
Avewt2k	51.3	5.06	36.7	51.5	61.6	232
Aveuac2k	24.3	1.74	18.9	24.2	28.8	232
avetric	4.74	1.12	2.3	4.55	9.9	222
Ave bmi	19.87	1.49	15.87	19.74	23.75	231

Ave age 39.29 males 20.1- 80.3

This is the male table to compare Hiernaux

Males 20-50	Mean	Sd	Min	Median	Max	N
ht	161.4	6.04	143.0	161.8	180.0	174
wt	52.1	4.77	38.9	52.1	61.6	174
Uac	24.55	1.67	18.9	24.5	28.8	174
Tric	4.79	1.14	2.95	4.56	9.9	168
bmi	20.01	1.41	15.9	19.5	23.7	173

Ave age males 31.8

Females 20-85	Mean	Sd	Min	Median	Max	N
Ht	150.7	5.95	133.1	151.0	168.2	285
Wt	46.1	5.58	30.9	45.75	61.4	285
Uac	23.6	2.0	19.0	23.36	29.5	285
Tric	11.3	4.3	4.1	10.5	29.0	279
Bmi	20.2	1.82	15.1	20.02	26.5	283

Females 20 – 50	Mean	Sd	Min	Median	Max	N
Ht	151.4	6.0	134.9	152.0	168.0	204
Wt	46.9	5.6	35.3	46.5	61.4	204
Uac	23.7	2.05	19.4	23.3	29.5	204
Tric	11.3	4.4	4.9	10.3	29.5	200
bmi	20.4	1.9	16.3	20.2	26.5	202

Ave age fem 20-50: 31.3 Median of individual ave fem wt 46.6 age 20-50

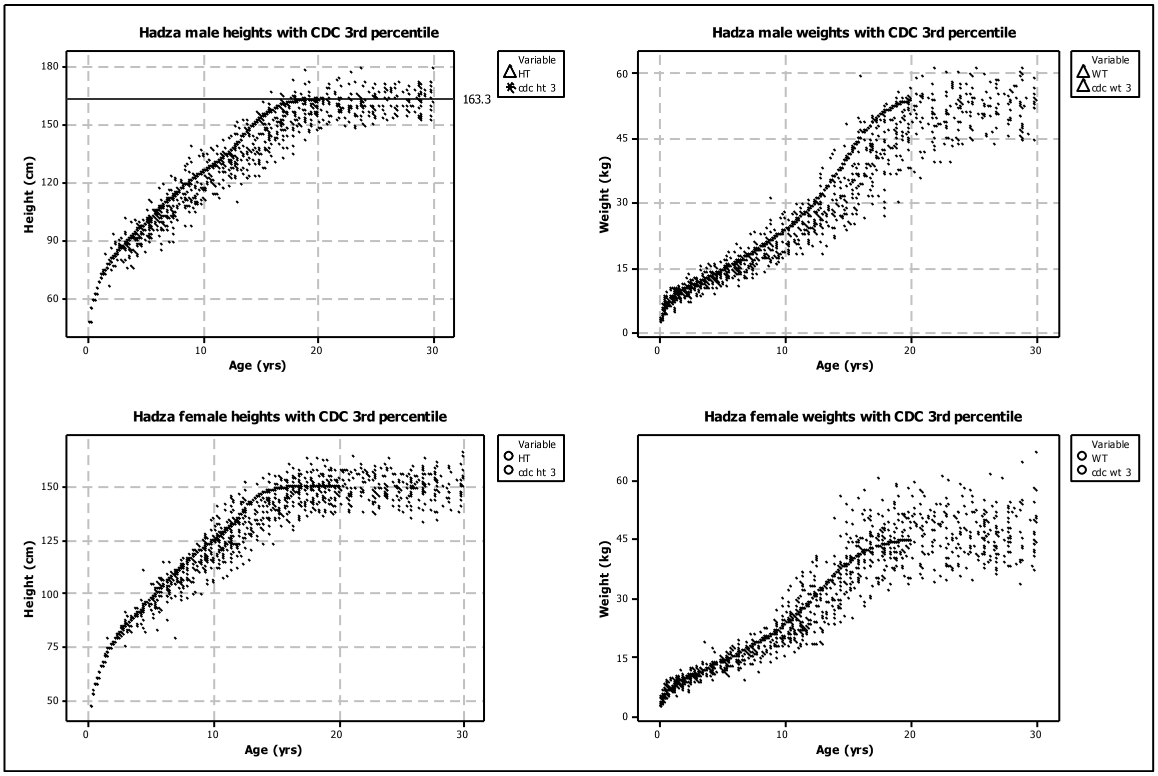
Eveleth & Tanner 1976 table 75 includes the Hadza (from IBP data, Hiernaux & Hartono 1980) compared to other African populations. Hadza men are some 7cm, and women 6 cm, shorter than the medians, and men 5 kg lighter, women 4 kg lighter.

Measurements of adult Hadza men and women by ethnicity of father.

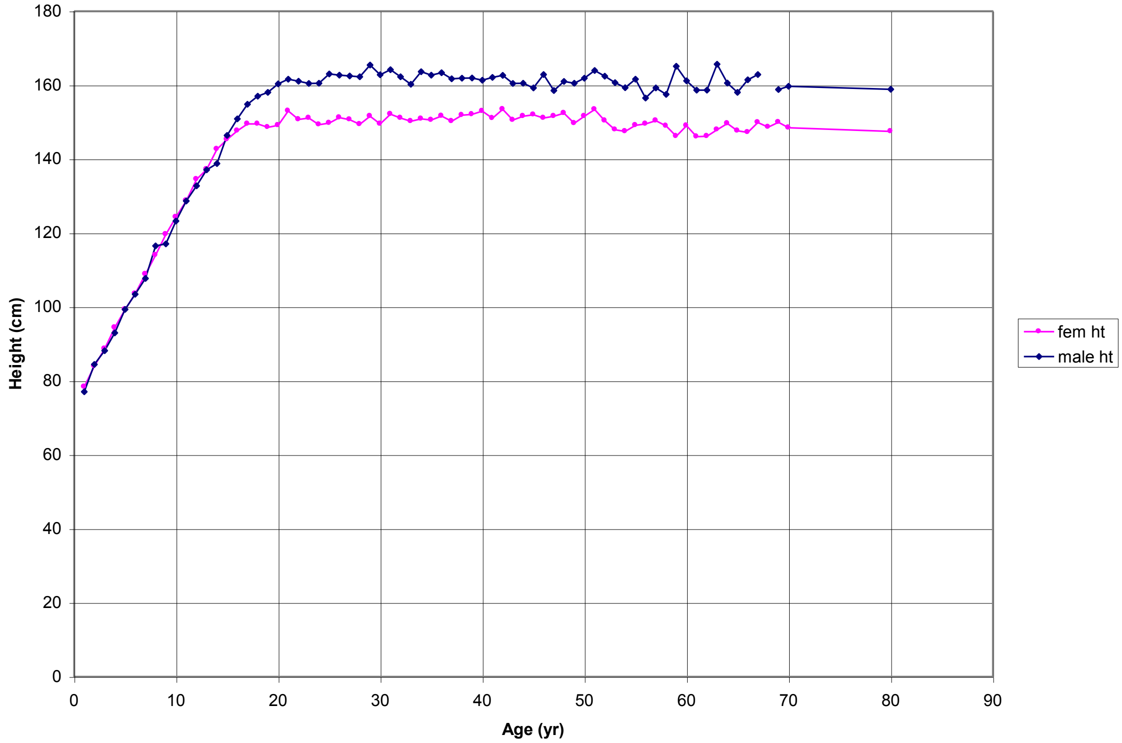
Males	N (H vs Sw)	Mean (Hadza fathers)	Sd	Mean (Swahili fathers)	Sd	p
Height	531 vs 14	161.4	6.33	163.0	3.05	.078
Weight	509 / 13	51.7	4.8	56.3	4.0	.002
UAC	531 / 14	24.6	1.8	25.9	2.4	.059
Tric1	476 / 13	4.6	1.26	4.9	1.59	.432
Tric 2	475 / 13	4.6	1.3	4.9	1.5	.576
BMI	502 / 13	20.0	1.53	21.2	1.96	.042

Females	N (H vs Sw)	Mean (Hadza fathers)	Sd	Mean (Swahili fathers)	Sd	p
Height	763 / 10	150.1	6.01	155.3	4.13	.003
Weight	754 / 10	45.55	5.49	45.99	4.39	.758
UAC	763 / 10	23.68	2.2	22.91	1.88	.229
Tric1	714 / 9	11.14	5.09	10.69	4.19	.755
Tric 2	713 / 9	11.14	5.16	10.0	3.19	.322
BMI	753 / 10	20.21	1.89	19.03	0.919	.003

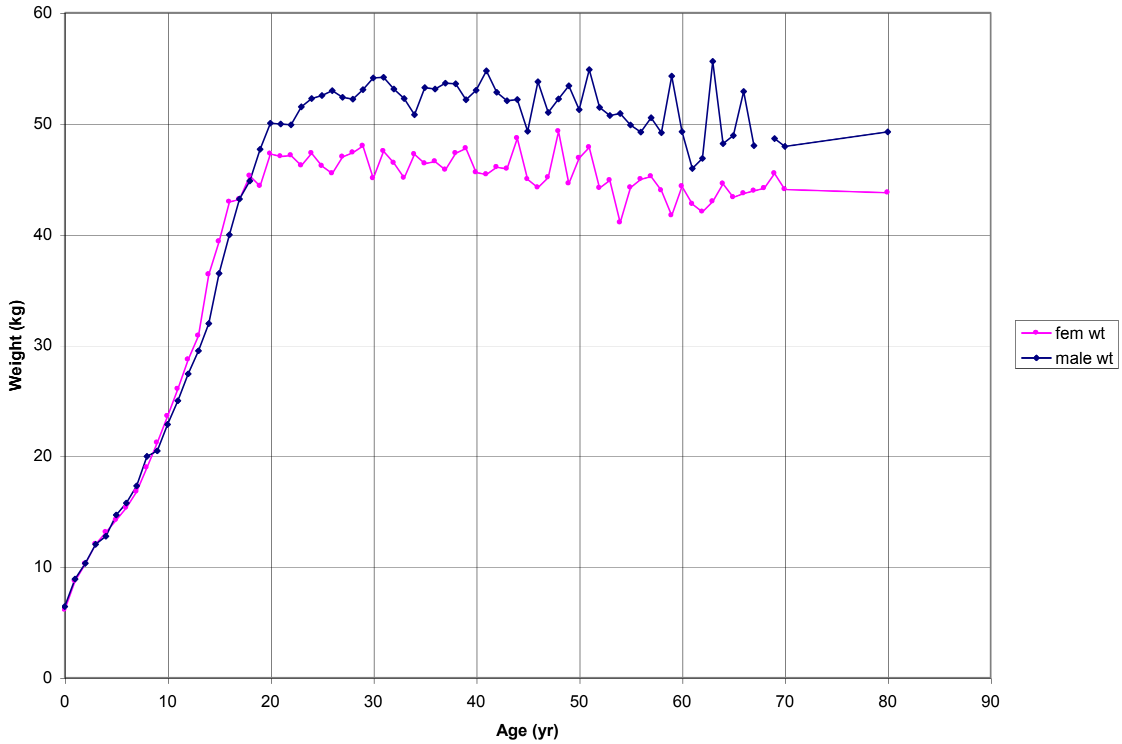
Height and weight measurements of Hadza x age.



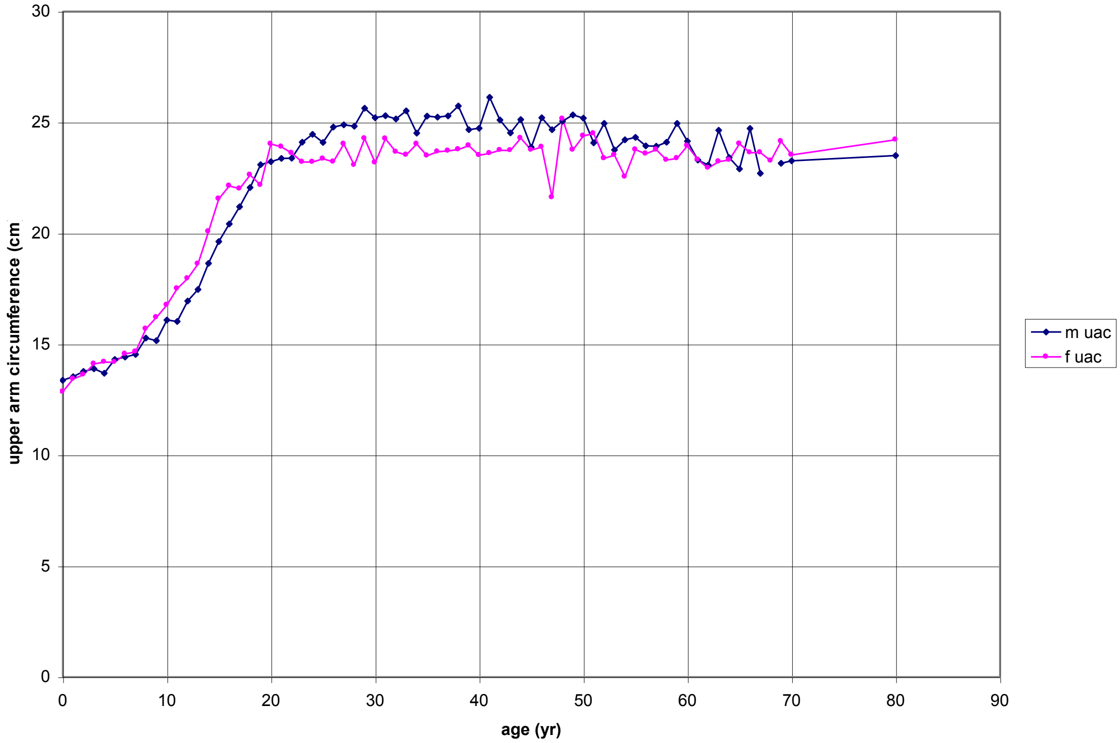
Average height x age.



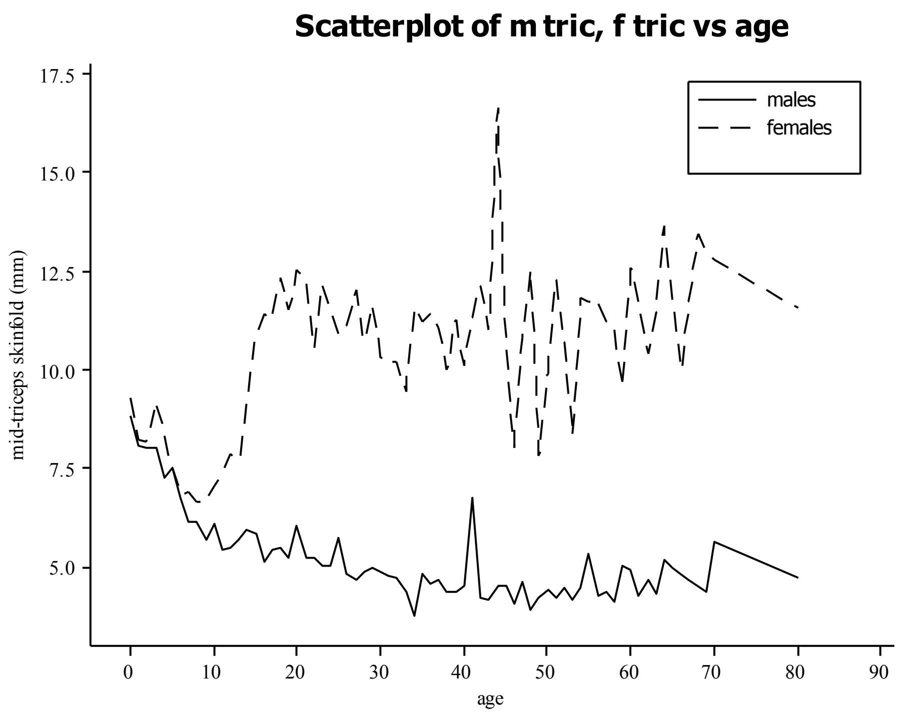
Average weights x age.



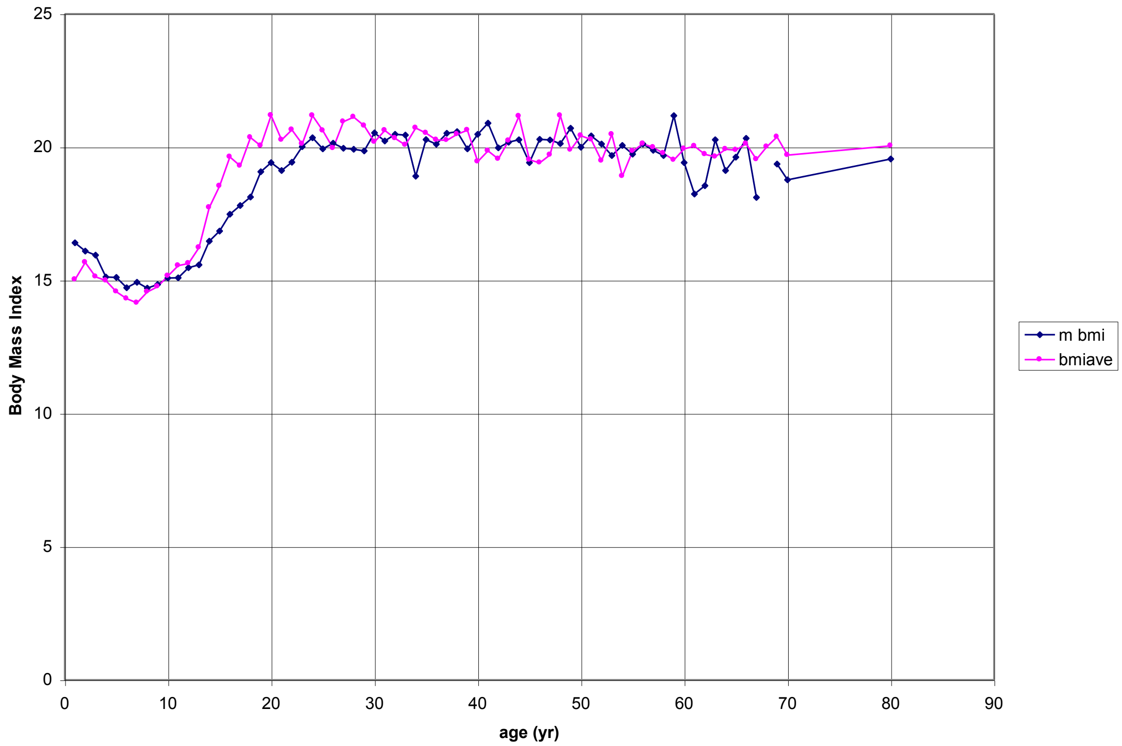
Hadza Upper arm circumference (cm) x age.



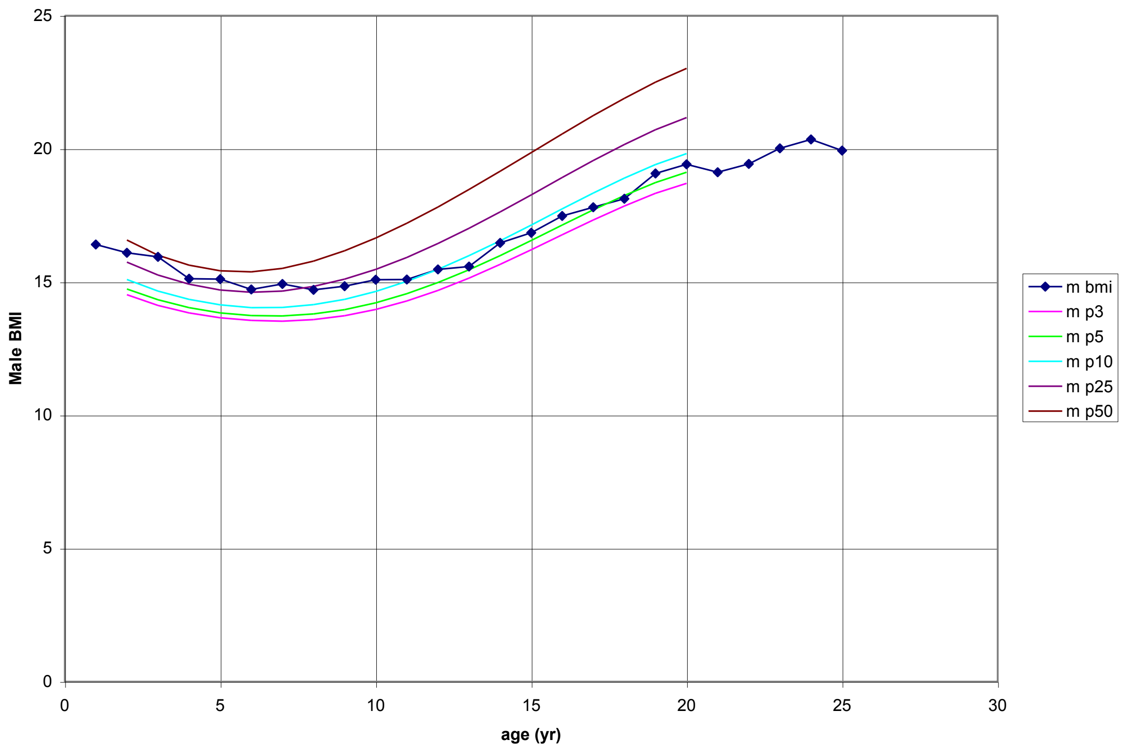
Triceps skinfold averages x age.



Hadza Body Mass Index x age. BMI as weight in kg / (height in metres ^2).



BMI of boys and young men plotted with CDC standards.



BMI of girls and young women plotted with CDC standards.
[only 4 cases at age 1]