**PREPRINT**

# Timing of pubertal growth and menarche in indigenous Qom girls of Argentina

**doi.org/10.1080/03014460.2018.1486455**

This is the final version of the article submitted to the Annals of Human Biology
Accepted 4 June 2018 and published online 22 Jul 2018
(Figures and tables follow references)

Authors: Melanie A. Martin[a]* and Claudia Valeggia[a]

[a]Yale University
Department of Anthropology

*Corresponding author current contact information:
Melanie A. Martin
martinm7@uw.edu
University of Washington
Department of Anthropology
orcid.org/0000-0003-0368-2791

## Abstract

**Background:** Pubertal timing is in part mediated by environmental factors, with greater energy availability often associated with earlier or more rapid development. Many indigenous populations are undergoing socioeconomic change that may affect pubertal development and related health risks, necessitating fundamental longitudinal research on growth and development in these populations.

**Aim**: We describe growth velocity and time to menarche among peri-urban indigenous Qom (Toba) girls in Argentina.

**Subjects and Methods:** From 2011-2015, monthly anthropometrics and menstrual status were collected from 61 Qom girls aged 7-14. Growth velocity curves were generated using the 'Super-imposition by translation and rotation' (SITAR) method. Median time to menarche was estimated by Kaplan-Meier survival analysis.

**Results:** Mean ages at peak height, weight, and BMI velocity were estimated at 10.8, 10.5, and 10.7 years, and median age at menarche at 11.6 years (95% CI 11.4 – 11.9).

At menarche, 45% of girls were overweight or obese and only one participant was short-statured by international standards.

**Conclusion:** Qom participants in this study exhibit relatively fast pubertal development as compared to other Latin American indigenous populations studied previously by others. Genetic and environmental factors influencing body size, diet, and/or activity levels should be investigated further in this population.

**Keywords:** puberty, growth and development, Latin America, indigenous health, menarche

## Introduction

The onset and pace of pubertal progression are flexibly attuned to environmental conditions (Ellis, 2004; Ellison et al., 2012), with earlier maturation generally associated with greater available energetic resources and more rapid growth during childhood (Ellison, 1990, 2001). Earlier pubertal maturation in females has been observed globally since the 20$^{th}$ century (Parent et al., 2003; Biro et al., 2012), and is a growing public health concern, since earlier onset of menstruation and gains in adiposity may increase later life risk of reproductive cancers, obesity, and other metabolic diseases (Stoll, 1998; Stöckl et al., 2011; Akter et al., 2012; Glueck et al., 2013). In certain cultural contexts, earlier sexual maturation may also lead to earlier sexual activity and increase risks of early adolescent pregnancy, sexually transmitted diseases, sexual abuse, depression, or anxiety (Angold et al., 1999; Kaestle et al., 2005; Boden et al., 2011).

Variation in pubertal development by socioeconomic class or ethnicity within populations is of further interest, as such variation may both reflect underlying differences in environmental quality or risk exposures, and predict later health disparities. National surveys from Brazil, Argentina, and Colombia have shown that earlier menarche is associated with higher income, better education, and greater birthweight, height, and BMI (Orden et al., 2011; Castilho and Nucci, 2015; Jansen et al., 2015). However, comparative research on pubertal development in Latin America by ethnicity and genetic ancestry has been limited. Though Latin American indigenous populations are generally economically marginalized, poverty may increase risks of over- or undernutrition depending on the quality of diet and other local conditions (Monteiro et al., 2004; Caballero, 2005), suggesting varying influences on pubertal development. For example, in the U.S. menarche generally occurs earlier among girls of lower socioeconomic status (Obeidallah et al., 2000; Krieger et al., 2015), who also tend have higher obesity risks (Drewnowski and Darmon, 2005; Frederick et al., 2014). In contrast, a study in Chile found that Mapuche indigenous girls were shorter, heavier and had later ages at menarche than their non-indigenous peers, with earlier menarche across both groups associated with higher stature and SES, not greater weight or BMI (Amigo et al., 2010, 2015, Ossa et al., 2010, 2012).

The Qom (Toba) are an indigenous population residing primarily in the northeastern Gran Chaco region of Argentina. Most Qom live below the national poverty level. However, mean height-for-age (HAZ) and BMI-for age z scores (BMIZ) of Qom children aged 0 – 18.9 years are well within normal ranges of international and national growth references (Alfonso-Durruty and Valeggia, 2016), and Qom adult stature is among the highest of small-scale indigenous populations surveyed globally (Walker et al., 2006). The prevalence of obesity and metabolic disorders in this transitioning population has also been steadily increasing (Valeggia et al., 2010; Lagranja et al., 2014a). Qom developmental trajectories may be either relatively slow or fast, given that the Qom are an economically marginalized South American indigenous population, but conversely relatively tall and well-nourished. In this descriptive study, we analyse patterns of growth velocity, time to menarche, and additional measures of nutritional status and pubertal development from a longitudinal study of pubertal Qom females. We compare Qom pubertal trajectories to those of other sample populations previously published, emphasizing Latin American and indigenous populations where possible.

## Materials and Methods

### *Study population*

The Qom of Argentina (referred to as "Toba" by neighbouring, but not related, indigenous groups) were traditionally semi-nomadic hunter-gatherers, who resisted Spanish colonization and Argentinian expansion policies until the late 1800s (Valeggia and Tola, 2003). Since the 1930s, government policy and habitat degradation have forced many Qom into peri-urban settlements. The total population today is around 70,000, with most Qom residing in the provinces of Chaco and Formosa, and in smaller settlements around Santa Fe and Buenos Aires. This study was conducted with girls in the peri-urban village of Namqom, a genetically homogenous Eastern Qom settlement (pop. ~3000), located 11 km outside of the city of Formosa (pop 234,000), and established in the early 1970s (Alfonso-Durruty and Valeggia, 2016).

Namqom families subsist primarily on government subsidies, with additional income generated from men's temporary wage labor and women's sales of artisanal crafts. The typical diet in Namqom is high in carbohydrates and fat from staples like *torta frita* (fried bread) (Lagranja et al., 2014b). Thirty-five and 45% of adults are classified as obese and overweight, respectively (Lagranja et al., 2014a). In more rural

Qom communities BMI is positively associated with socioeconomic status (Valeggia et al., 2010), though this relationship may be reversed in peri-urban Namqom.

A health center in Namqom offers prenatal and child health care, and the majority of births take place in a local city hospital. The incidence of pre-term births is comparable to that of non-indigenous women in the area. The majority of infants are within normal birth weight range (2500 – 4000 g), with 0- 3% classified as low birthweight and 10-12% as more than 4000g. In general infants are exclusively breastfed until about four to six months of age and weaned when the mother gets pregnant again, or the child weans him/herself (Valeggia and Ellison, 2003a; b; Olmedo et al., 2014). Adolescent sexual activity, including prostitution, is not stigmatized but may pose health risks. The average age at first birth is 16. Adolescent mothers usually remain single and live at home, and it is common of them to foster away care of their first born children to parents or other relatives (Valeggia and Tola, 2003).

***Ethics approval and consent to participate***

Participants and their caretakers were informed that the purpose of the study was to examine pubertal development in the population. All girls and their adult caretakers (usually the mother) provided verbal informed consent to participate. The research protocol was approved by the internal review boards of both the University of Pennsylvania (Protocol # 811200) and Yale University (HSC Protocol # 1406014104). There were no ethics committees available to provide approval in the province of Formosa, where the study took place.

***Data collection***

Between 2011 – 2015, researchers affiliated with the Chaco Area Reproductive Ecology (CARE) program followed a total of 61 self-identifying Qom girls between the ages of 7 -14. This data was collected as part of a larger study to examine endocrine correlates of female reproductive life history transitions. *Subject recruitment:* All females aged 7-10 in Namqom were eligible for inclusion in the study and invited to participate. As Qom families move frequently among kin residences and across territories, participants were located and recruited into the study between 2011-2013 (Table 1). To our knowledge, there were no girls aged 7-10 living permanently in the community during those years who were approached and excluded based on menarcheal status, or who declined to participate. However, at the start of data collection in January 2011, four pre-menarcheal girls aged 12-13 requested to be part of the study and were also included. To test if inclusion of these subjects biased results, we ran separate survival analysis models of time to menarche both including and excluding these subjects. The average age at first observation across all participants was 9.4 ± 1.2 years (range 7.3 – 13.4; IQR 8.4 – 10.9).

*Subject follow-up:* The original study design protocol called for researchers to follow participants monthly until they reported menstruating three times or for six months after menarche. The total number of observations per subject per year varied due to age at initial observation, age at menarche, age at study exit, and intermittent absences (Table 1). Age at menstruation was reported by 51/61 participants: three participants had still not experienced menarche by the end of the study in 2015 (mean age at last observation 12.3 ± 0.7 years; mean number of observations 37 ± 4); one participant left the study at her mother's request at age 8.7 after five visits; six participants moved away or were otherwise lost to follow up (mean age at last observation 9.7 ± 1.1 years; mean number of observations 12 ± 13). The mean number of observations per subject was 24 ± 11 (range 2 - 46, IQR 16 - 29). Among participants with known age at menarche, the mean number of pre- and post-menarcheal observations per subject were 20 ± 4 and 4 ± 3, respectively, and the mean age at last observation was 12.0 ± 1.0 (range 9.9 – 14.4).

*Measurement protocols*: Anthropometric measures and self-reported menstrual status and Tanner breast stage were collected by researchers during monthly visits to the participants' homes. Height was measured to the nearest centimeter using a portable SECA 213 portable stadiometer. Chest, waist, and hip circumference were measured to the nearest 0.5 cm using a portable tape measure. Weight (kg) and % body fat (via electrical impedance) were recorded using TANITA ® body composition scale. Tricep and subscapular skinfolds were measured in triplicate to the nearest mm using Lange calipers. Participants were also given photographs of Tanner breast stages digitally modified with darker skin images to reference, and asked to self-report their own stage of development. However, in 39% of interviews, participants declined to report this information. Maternal age at menarche and participants' birth weight, birth length, and gestational age from birth records were collected at initial interviews if available.

***Statistical analysis***

All statistical analyses were run on R (ver. 3.4.1). Descriptive statistics were generated for each of the following anthropometric measurements at initial observation and at age of menarche: weight, height, BMI, % body fat, waist, hip, and chest circumference, waist to hip ratio, and subscapular and triceps skinfold measurements. Triplicate measures of subscapular and tricep skinfolds were averaged for each observation. Height-for-age (HAZ) and BMI-for-age z-scores (BMIZ) were calculated using WHO 2007 growth standards (de Onis et al., 2007). HAZ and weight-for-age z scores (WAZ) were also calculated based on Argentina LMS pediatric growth references (Lejarraga et al., 2009). To account for intermittent missing self-reported Tanner breast stages, we assigned a median breast stage score to each six-month period of observation for each participant. Kaplan-Meier survival analysis was used to estimate median time to menarche to incorporate both censored (n = 10) and non-censored participants (n = 51).

SITAR models of height, weight, and BMI velocity were generated using the *sitar* package in R (Cole, 2017). The method has been previously used to model height velocities of European and South American children (Cole et al., 2014; Blackwell et al., 2016b). As described in more detail elsewhere (Cole et al., 2010; Pizzi et al., 2014), the SITAR method uses a shape invariant spline curve and a nonlinear random-effects model to fit individual trajectories and estimate an average growth curve for a sample. The model estimates three fixed and random effects ($\alpha, \beta, \gamma$), referred to as *size, tempo,* and *velocity*, which define how individual curves deviate from the mean (Cole et al., 2010). For each growth outcome, *size* is interpreted as a random intercept, with larger values representing larger mean size than average (an upward shift of the curve). *Tempo* adjusts for differences in the age at peak velocity (APV), with positive values indicative of later maturation and negative values indicative of earlier maturation relative to the mean (right or left shifts of the curve). *Velocity* adjusts for the duration of the growth spurt, with positive values indicative of faster and negative values of slower growth (stretching or shrinking the curve along the age scale).

To ensure model convergence, we constrained all observations to equivalent intervals by rounding each age at measurement in years to the nearest 1$^{st}$ decimal (e.g. 8.1, 8.2, 8.3). In the case of multiple measures per individual in an interval, only the first measure was retained. We eliminated from the sample any age intervals with fewer than five subjects per interval, and any subjects with fewer than three observations. The resulting sample included 58 subjects ages 8.0 – 13.0, with 1174 height observations and 1171 weight/BMI observations. Final models for height, weight, and BMI were all fit with a five-degree polynomial curve.

Prior to assembling the database used in this study, raw data points were visually inspected. Biologically implausible measures (monthly deviations of > 2 cm or > 5 kg from previous or subsequent measures) were checked against written records and amended, or removed in extreme cases. For the SITAR models, we examined additional outliers within individual trajectories using custom package functions. Removal of weight and BMI outliers substantially reduced the sample, resulting in an altered weight velocity curve and non-convergence of the BMI velocity model. Since errors appeared randomly distributed across subjects, and there was a high number of discrete data points per subject, we ultimately elected not to remove flagged outliers from the final models. Growth velocities calculated over measurement increments of < 0.85 years are more affected by seasonal shifts and measurement error (Tanner and Davies, 1985). However, SITAR growth models for Qom girls did not converge when the dataset was reduced to measurements taken every 3 or 6 months, likely due to the resulting small sample size. Removal of one subject observed to be an extreme outlier for weight (mean 84.7 ± 11.4 kg) and BMI (mean 37.0 ± 2.8) resulted in biomodal growth velocity distributions or nonconvergence of models. In general, the SITAR models were highly sensitive to any data reduction. A model of fat velocity, with % body fat measured from bioelectrical impedance, also failed to converge. Velocity curves and estimates for peak velocity and age at peak velocity were generated from *sitar* package custom commands. Datasets and R code used to generate analyses are publically available on figshare (https://doi.org/10.6084/m9.figshare.4757164.v2).

## Results

Eighty percent of Qom girls with known age at menarche (40/51) experienced menarche before age 12. The median time to menarche estimated by survival analysis for censored and non-censored subjects was 11.6 years (95% CI 11.4 – 11.9) (Fig.1), which was largely concordant with mean and median ages from girls with known age at menarche (Table 2). Median time to menarche was slightly decreased by removing the four pre-menarcheal subjects who were aged 12-13 at first observation from the survival analysis (11.4, 95% CI 11.3 – 11.8). There are no standard cut-offs for defining early menarche, with researchers varyingly using population cut-offs of < 11 to < 12 years (Ibáñez et al., 2006; Stöckl et al., 2011; Akter et al., 2012; Glueck et al., 2013). We estimate that 77% (66 – 89% 95% CI) of Qom girls are still premenarchal at age 11, and only 31% (21-47%) at age 12. (Figure 1). For subjects' mothers with available data (n = 48), their average age of menarche reported by recall was 12.81 ± 1.08, suggesting a secular trend towards earlier pubertal development. Participants and their mothers' reported ages at menarche were weakly correlated (Pearson's $r$ = 0.337, 95% CI = 0.041 – 0.579; $p$ = 0.027).

Precocious thelarche is frequently diagnosed if breast development is observed before age 8, ideally confirmed by palpation in a supine position (Kaplowitz and Bloch, 2015). We lack appropriate diagnoses for precocious thelarche based on these criteria, and only two subjects observed at age seven ever self-reported breast stage, both reporting stage I development. Across all participants observed from ages 7-9 (n = 57), in 59% of monthly observations (226/381) participants reported Tanner Stage I breast development, 36% (138/381) reported Stage II, and 5% (17/381) reported Stage III-V. Among subjects reporting menarche, 7% (3/51) reported Stage I breast development in the month of menarche, 64% (29/51) Stage II, 27% Stage III (12/51), and 2% (1/51) Stage IV.

For participants with available data, most were born within normal birthweight ranges, though 5% (3/58) would be classified as low birthweight (< 2.5 kg) and 9% (5/58) as macrosomic (> 4 kg). For subjects with known gestational ages, 23% (9/39) were classified as preterm at < 37 weeks. At initial observations, 26% of participants were overweight and 8% were obese, with only 7% classified as short-statured (Table 3). By menarche, the percentage of short-statured girls slightly decreased while percentages of obese and overweight girls slightly increased (Table 3). Mean HAZ scores at menarche were well within normal ranges as calculated by either WHO standards or Argentina growth references (Table 2).

There have been limited studies to determine cut-offs for abdominal obesity based on waist circumference or waist/height ratios in children, and cut-off values may vary with age and ethnicity (Lear et al., 2010; Lewitt et al., 2012; Magalhães et al., 2014). Waist circumference cut-offs of ≥ 70.1 and ≥ 69.9 cm have been recommended for Mexican girls aged 8-9 and 10 year-old, respectively (Gomez-Diaz et al., 2005), and 65.1 – 69.1 cm for mixed-ethnicity Chinese girls aged 7 – 18 (Yan et al., 2008). Waist-height ratio cut-offs of > 0.44 and > 0.43 cm have been recommended for Brazilian girls aged 8 and 9 (Sant'Anna et al., 2010), and 0.475 – 0.50 for Chinese, Spanish, and Italian children up to age 18 (Yan et al., 2007; Maffeis et al., 2008; Marrodán et al., 2013). Conservatively, we applied cut-off values of ≥70 cm for waist circumference and ≥ 0.50 for waist/height ratio as potentially indicative of abdominal obesity. At first observation (n = 61), 11% of participants had a waist circumference of ≥70 cm and 25% had a waist/height ratio ≥ 0.50. For participants reporting menarche (n = 51), the prevalence was 43% and 25%, respectively, at month of menarche. Waist/height ratio at first observation was not associated with age at menarche after adjusting for age at first observation (Est. = -2.2, 95% CI = -7.21 – 2.28; $p$ = 0.381).

As estimated by SITAR models, mean age at peak velocity and mean peak velocity were estimated at 10.8 years and 9.4 cm/years for height, and 10.5 years and 8.5 kg/year for weight. Mean age at BMI velocity was estimated at 10.7 years. Velocity and distance curves for each growth measure are shown in Figures 2a-c. The models explained 98.8%, 99.1, and 97.8% of variance in height, weight, and BMI, respectively. Random effects for size and tempo were positively correlated in models of height (0.63), weight (0.61), and BMI velocity (0.60), indicating that later maturation is associated with greater average body size. Growth velocity was more strongly correlated with size and tempo in models of weight (size/tempo 0.62/0.80) and BMI (0.58/0.56) than in models of height (0.14/0.32).

**Discussion**

There have been relatively few longitudinal studies on growth and menarcheal onset in indigenous populations, limiting knowledge of normative variation in pubertal development globally. Pubertal development among the Qom girls observed here appears relatively accelerated when compared to available published estimates of growth velocity in indigenous and non-indigenous populations. To our knowledge, only two studies have used similar methods—i.e. SITAR curves or pseudo-velocity curves from median LMS values—to characterize pubertal growth in indigenous populations. These were conducted with neotropical horticulturalist populations, the Tsimane of Bolivia and the Shuar of Ecuador. For both height and weight, mean peak velocities are greater and mean ages of peak velocity are earlier in Qom as compared to Tsimane females (height: 8.2 cm/yr, 11.3 years; 6.5 kg/yr, 12.0 years) (Blackwell et al., 2016b).

Comparatively, Shuar females exhibited a slightly earlier mean age of peak height velocity (10.2 years), but later mean age at peak weight velocity (12.1 years) and substantially lower velocities for height and weight (5.4 cm/yr, 2.2 kg/yr, 12.1 years) (Urlacher et al., 2015).

Differences in pubertal growth between the Qom and these indigenous populations are expected due to substantial intra-and inter-population environmental and genetic variation. For example, the Tsimane and the Shuar are characterized by short adult stature, a high prevalence of childhood stunting and infectious diseases, and relatively low prevalence of overweight/obesity (Godoy et al., 2006; Blackwell et al., 2010, 2016a; Liebert et al., 2013; Rosinger et al., 2013; Urlacher et al., 2016). In contrast, the average height of Qom adults are among the highest documented for indigenous groups globally (Walker et al., 2006), and 35% and 45% of Qom adults are obese and overweight, respectively (Lagranja et al., 2014a).

Estimated peak height velocity for these participants is also earlier as compared to estimates of 11.5 – 12.1 years published in seminal studies of American and European girls observed from the 1960s – 1990s (Tanner, 1989; Abbassi, 1998; Granados et al., 2015). The SITAR method was recently applied to a study of English girls measured in the 1970s (Cole et al., 2014), and estimated age at peak height velocity and peak velocity in those subjects at 11.9 years and 7.6 cm/year, respectively. In an early study of pubertal growth in North American children, early maturation was noted to coincide with greater peak height velocity (Tanner and Davies, 1985). In Qom girls, the estimated age at peak weight velocity preceded age at peak height velocity by ~ four months, whereas elsewhere peak height velocity has been reported to precede peak weight velocity by about six months elsewhere (Rogol et al., 2000). Average peak height velocity of Qom girls also preceded average age at menarche by approximately

9.6 months, whereas an average difference of about one year between these events was estimated for English girls measured in the 1970s (Cole et al., 2014). The growth differences observed in these comparisons may reflect local genetic and obesogenic conditions, but also general secular trends operating across disparate observation periods.

At ~11.5 years, menarche also occurs on average about 6 months to 2 years earlier in these Qom girls than as reported in recent studies for girls in the U.S., Europe, and Latin America, including Argentina (Ossa et al., 2010; Orden et al., 2011; Torres et al., 2011; Currie et al., 2012; Cabrera et al., 2014; Castilho and Nucci, 2015; Jansen et al., 2015; Krieger et al., 2015), and may reflect the influence of obesogenic conditions as observed elsewhere. For example, average ages of menarche around 11.5 years or earlier have been observed and associated with excess weight and/or body fat in girls from the Brazilian Amazon (Barcellos Gemelli et al., 2016), Yucatán, México (Datta Banik et al., 2015), Italy (Rigon et al., 2010), and Argentina (Figueroa Sobrero et al., 2016). Similarly, a comparative study of pubertal development in children from Bolivia (Takana and Esse ejja ethnicities) and Senegal (Tokolor, Wolof, and Serer ethnicities), all of whom lived in rural, tropical environments, found that the characteristically "short and plump" Bolivian girls had much earlier ages of menarche (median 12.9 years) than the characteristically "tall and thin" Senagalese girls (median 15.9 years) (Benefice et al., 2011). Average ages of menarche around 11.5 years have also been associated with relative affluence in specific demographic groups within populations—e.g.: Saudi Arabian girls attending private schools (Shaik et al., 2015), and Mexican girls born after 1990 (Marván et al., 2016). Finally, while Mapuche girls in Chile experience menarche 2-4 months later on average than non-indigenous neighbouring girls (Amigo et al., 2010, 2012; Ossa et al., 2012), among the Mapuche themselves, researchers have observed a secular trend in decreasing age at menarche since the 1960s (Ossa et al., 2010), and earlier menarche in association with obesity and higher socioeconomic status (Amigo et al., 2012).

Qom environmental and genetic conditions influencing infant and childhood growth patterns may influence relatively accelerated pubertal development. The present study suggests a picture of sufficient to excess nutrition in later childhood, as at first observations 24% of participants were overweight, 8% were obese, and only 7% were short-statured. A previous survey showed that mean HAZ in Qom children increased in each successive age group following infancy, while mean WAZ was u-shaped (with a nadir during ages 3-6), and mean BMIZ was lower in each age group following infancy, levelling off after age 11. Mean BMIZ in infants (0-2.9 years) of both sexes and across all regions was $1.64 \pm 1.18$, which is notable because Qom infants are exclusively breastfed for about six months and breastfed for about 2-3 years. Mean HAZ was also significantly higher among more rural Western Qom than among peri-urban Eastern Qom (Alfonso-Durruty and Valeggia, 2016), suggesting a wider underlying genetic influence.

We have previously proposed that Qom growth patterns—i.e. decreasing mean BMIZ and increasing mean HAZ after infancy—may reflect an evolutionarily selected strategy (Alfonso-Durruty and Valeggia 2016). Life-history theory posits that somatic energy expenditure at key phases of the life course may be shaped by selection to maximize survival or reproduction through differential energy allocation. Energy trade-offs can occur between investment in growth, reproduction, or maintenance, but also within those individual categories, for example between linear growth and adiposity. Preferential investment in adiposity (maintenance) relatively to linear growth during infancy may buffer against energy losses related to infectious disease and nutritional scarcity, and therefore may be common strategy in risky environments (Ellison 2001; Walker et al., 2006). Conversely, the observed gains in linear height during childhood and adolescence—which result in larger adult body size relative to other small-scale populations (Walker et al., 2006)—may reflect energetic adaptations to the Chacoan ecology and/or relaxed selection pressures from infectious disease burdens post-infancy.

**Limitations and Future Directions**

A strength of our study is the longitudinal design with multiple, discrete measurements per subject. Longitudinal research on growth and development in indigenous populations in particular has been limited. While participants in this study represented all available female subjects in the study village at the time, the study design is unbalanced due to participants entering and exiting the study at different ages, rather than according to set observational windows. Analysis of pubertal development according to Tanner stages was not possible because of cultural sensitivity issues, which limited data collection to self-reported breast development, with participants frequently declining to report this information. Finally, though recall bias for age at menarche was minimized through monthly visits, we cannot rule out inaccurate self-reporting.

Analysis of causal factors associated with variation in pubertal growth is beyond the scope of this dataset. While shorter gestational age, low birth weight, and more rapid postnatal catch-up growth have been associated with earlier pubertal maturation (Wehkalampi et al., 2011; Addo et al., 2014), we lacked sufficient data to investigate these relationships among our participants. Similarly, while over a third of participants in our study were overweight or obese at initial observations, additional longitudinal research beginning in mid-childhood would be necessary to assess whether the patterns of pubertal development observed here are reflective of age at pubertal onset, the pace of pubertal development, or both. Ongoing research stemming from this study will investigate the relationship between growth velocity and concordant changes in metabolic, reproductive, and immunological urinary biomarkers, which may provide more insight into cumulative energetic influences on pubertal development.

Additional longitudinal research would be necessary to assess differences in pubertal maturation between Qom and more affluent non-Qom residents of Formosa. If pubertal development among the Qom does indeed occur relatively earlier, the pattern may be more analogous to that observed in the U.S., in which lower SES and minority groups tend to have earlier ages at menarche but also greater BMI and earlier skeletal maturation (Bogin, 1999; Obeidallah et al., 2000; Kelly et al., 2014). In this case, future research should also explore local patterns of pubertal development in relation to variation in diet, activity, early growth trajectories, and exposure to endocrine disrupting chemicals or specific dietary components. Such research may help determine to what extent early pubertal development in the Qom may be genetic or owing to modifiable socioeconomic and cultural factors. Finally, while early adolescent sexual activity and pregnancy among Qom girls are common and culturally accepted, additional research may examine if differences in pubertal trajectories within the population influence variation in subsequent sexual activity, timing of first births, or later life metabolic or reproductive health risks.

**Conclusions**

We have described pubertal growth and age at menarche in a sample of indigenous Qom girls from a peri-urban village in Formosa, Argentina. Mean ages at peak height velocity (10.8 years) and menarche (11.6 years) of participants were relatively early compared to estimates reported in several other studies of girls in Latin America, U.S., and Europe. Accelerated pubertal development in these girls may reflect local energetic factors—including a high carbohydrate-high fat diet and sedentarism—and population specific growth patterns, characterized by marked adiposity in infancy and gains in linear height in later childhood. However, additional research on diet, activity, growth, and environmental exposures in a wider Qom sample and other local non-indigenous populations is needed to both confirm this pattern and illuminate possible causal relationships. This study underscores the importance of conducting longitudinal studies with diverse populations to better understand current global secular trends and variation in pubertal development.

**Acknowledgements**

We thank all participants and the study community for their cooperation. This study would not have been possible without the many contributions of the research coordinators and assistants of the Chaco Area Reproductive Ecology Program: Mirella Aglietta, Florencia Cirigliano, Rocio Davichi, Mandi Davichi, Marisa Galeano, Angie Jaimez, Silvia Mansilla, Fernanda Medina, Rosaura Medina, Cara McGuinness, Sofia Olmedo, Florencia Orlando, Alfonsina Salvarredy, Noemí Trope, and Monika Wasik. The staff at the Centro de Salud Namqom graciously provided access to clinical histories (with permission from participants). We thank Fundación ECO for their logistical, administrative, and moral support throughout data collection. Veronika Shabanova and Aaron Blackwell provided helpful analytical advice.

**Funding:**

This research was supported by NSF BCS-0952264. The Yale Institute of Biospheric Studies (YIBS) funded a postdoctoral fellowship for MAM

**Disclosure statement:**

The authors have no financial or other competing interests to declare.

**Supplemental online material**

All datasets and code available on figshare (https://figshare.com/projects/Qom_Puberty_Shared_Data/19756)

## References

Abbassi V. 1998. Growth and normal puberty. Pediatrics [Internet] 102:507–11. Available from: http://pediatrics.aappublications.org/content/pediatrics/102/Supplement_3/507.full.pdf

Addo OY, Miller BS, Lee PA, Hediger ML, Himes JH. 2014. Age at hormonal onset of puberty based on luteinizing hormone, inhibin B, and body composition in preadolescent US girls. Pediatr Res [Internet] 76:564–570. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25192395

Akter S, Jesmin S, Islam M, Sultana SN, Okazaki O, Hiroe M, Moroi M, Mizutani T. 2012. Association of age at menarche with metabolic syndrome and its components in rural Bangladeshi women. Nutr Metab (Lond) [Internet] 9:1–7. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3541253&tool=pmcentrez&rendertype=abstract

Alfonso-Durruty MP, Valeggia CR. 2016. Growth patterns among indigenous Qom children of the Argentine Gran Chaco. Am J Hum Biol [Internet] 0:1–10.

Available from: http://www.ncbi.nlm.nih.gov/pubmed/27350151

Amigo H, Bustos P, Muzzo S, Alarcón AM, Muñoz S. 2010. Age of menarche and nutritional status of indigenous and non-indigenous adolescents in the Araucanía Region of Chile. Ann Hum Biol 37:554–561.

Amigo H, Lara M, Bustos P, Munoz S. 2015. Postmenarche growth: cohort study among indigenous and non-indigenous Chilean adolescents. BMC Public Health 15:1–7.

Amigo H, Vasquez S, Bustos P, Ortiz G, Lara M. 2012. Socioeconomic status and age at menarche in indigenous and non-indigenous Chilean adolescents. Cad Saude Publica 28:977–983.

Angold A, Costello EJ, Erkanli A, Worthman CM. 1999. Pubertal changes in hormone levels and depression in girls. Psychol Med 29:1043–1053.

Barcellos Gemelli IF, Farias E dos S, Souza OF. 2016. Age at Menarche and Its Association with Excess Weight and Body Fat Percentage in Girls in the Southwestern Region of the Brazilian Amazon. J Pediatr Adolesc Gynecol 29:482–488.

Benefice E, Luna Monrroy SJ, Lopez Rodriguez RW, Ndiaye G. 2011. Fat and muscle mass in different groups of pre-pubertal and pubertal rural children. Cross-cultural comparisons between Sahelian (rural Senegal) and Amazonian (Beni River, Bolivia) children. Ann Hum Biol [Internet] 38:500–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/21696325

Biro FM, Greenspan LC, Galvez MP. 2012. Puberty in Girls of the 21st Century. J Pediatr Adolesc Gynecol [Internet] 25:289–294. Available from: http://dx.doi.org/10.1016/j.jpag.2012.05.009

Blackwell AD, Snodgrass JJ, Madimenos FC, Sugiyama LS. 2010. Life history, immune function, and intestinal helminths: Trade-offs among immunoglobulin E, C-reactive protein, and growth in an Amazonian population. Am J Hum Biol [Internet] 22:836–848. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20865759

Blackwell AD, Trumble BC, Maldonado Suarez I, Stieglitz J, Beheim B, Snodgrass JJ, Kaplan H, Gurven M. 2016a. Immune Function in Amazonian Horticulturalists. Ann Hum Biol [Internet] 4460:382–396. Available from: http://www.tandfonline.com/doi/full/10.1080/03014460.2016.1189963

Blackwell AD, Urlacher SS, Beheim BA, von Rueden C, Jaeggi A V., Stieglitz J, Trumble BC, Gurven MD, Kaplan HS. 2016b. Growth references for Tsimane forager-horticulturalists of the Bolivian Amazon. Am J Phys Anthropol:in submission.

Boden JM, Fergusson DM, Horwood LJ. 2011. Age of menarche and psychosocial outcomes in a new zealand birth cohort. J Am Acad Child Adolesc Psychiatry [Internet] 50:132–140. Available from: http://dx.doi.org/10.1016/j.jaac.2010.11.007

Bogin B. 1999. Patterns of Human Growth. 2nd ed. Cambridge Univ Pr.

Caballero B. 2005. A Nutrition Paradox — Underweight and Obesity in Developing Countries. N Engl J Med [Internet] 352:1514–1516. Available from: http://www.nejm.org/doi/abs/10.1056/NEJMp048310

Cabrera SM, Bright GM, Frane JW, Blethen SL, Lee PA. 2014. Age of thelarche and menarche in contemporary US females: A cross-sectional analysis. J Pediatr Endocrinol Metab 27:47–51.

Castilho SD, Nucci LB. 2015. Age at menarche in schoolgirls with and without excess weight. J Pediatr (Rio J) [Internet] 91:75–80. Available from:

http://dx.doi.org/10.1016/j.jped.2014.05.008

Cole T. 2017. sitar: Super imposition by translation and rotation growth curve analysis. Available from: https://cran.r-project.org/web/packages/sitar/sitar.pdf

Cole TJ, Donaldson MDC, Ben-shlomo Y. 2010. SITAR-a useful instrument for growth curve analysis. Int J Epidemiol 39:1558–1566.

Cole TJ, Pan H, Butler GE. 2014. A mixed effects model to estimate timing and intensity of pubertal growth from height and secondary sexual characteristics. Ann Hum Biol [Internet] 41:76–83. Available from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3877946/%5Cnhttp://www.ncbi.nlm.nih.gov/pmc/articles/PMC3877946/pdf/AHB-41-76.pdf%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/24313626

Currie C, Ahluwalia N, Godeau E, Nic Gabhainn S, Due P, Currie DB. 2012. Is obesity at individual and national level associated with lower age at menarche? Evidence from 34 countries in the health behaviour in school-aged children study. J Adolesc Heal [Internet] 50:621–626. Available from: http://dx.doi.org/10.1016/j.jadohealth.2011.10.254

Datta Banik S, Mendez N, Dickinson F. 2015. Height Growth and Percentage of Body Fat in Relation to Early Menarche in Girls from Merida, Yucatan, Mexico. Ecol Food Nutr [Internet] 54:644–662. Available from: http://dx.doi.org/10.1080/03670244.2015.1072814

Drewnowski A, Darmon N. 2005. The economics of obesity: dietary energy density and energy cost. Am J Clin Nutr [Internet] 82:265S–273S. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16002835

Ellis BJ. 2004. Timing of Pubertal Maturation in Girls: An Integrated Life History Approach. Psychol Bull [Internet] 130:920–958. Available from:

http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-2909.130.6.920

Ellison PT. 1990. Human Ovarian Function and Reproductive Ecology: New Hypotheses. Am Anthropol [Internet] 92:933–952. Available from: http://doi.wiley.com/10.1525/aa.1990.92.4.02a00050

Ellison PT. 2001. On Fertile Ground. Cambridge: Harvard University Press.

Ellison PT, Reiches MW, Shattuck-Faegre H, Breakey A, Konecna M, Urlacher S, Wobber V. 2012. Puberty as a life history transition. Ann Hum Biol 39:352-360.

Figueroa Sobrero A, Evangelista P, Kovalskys I, Digón P, López S, Scaiola E, Perez N, Dieuzeide G, Walz F, Mazza C. 2016. Cardio-metabolic risk factors in Argentine children. A comparative study. Diabetes Metab Syndr Clin Res Rev.

Frederick CB, Snellman K, Putnam RD. 2014. Increasing socioeconomic disparities in adolescent obesity. Proc Natl Acad Sci U S A [Internet] 111:1338–42. Available from: http://www.ncbi.nlm.nih.gov/pubmed/24474757

Glueck CJ, Morrison JA, Wang P, Woo JG. 2013. Early and late menarche are associated with oligomenorrhea and predict metabolic syndrome 26 years later. Metabolism [Internet] 62:1597–1606. Available from: http://dx.doi.org/10.1016/j.metabol.2013.07.005

Godoy RA, Leonard WR, Reyes-García V, Goodman E, McDade T, Huanca T, Tanner S, Vadez V. 2006. Physical stature of adult Tsimane' Amerindians, Bolivian Amazon in the 20th century. Econ Hum Biol [Internet] 4:184–205. Available from: http://www.sciencedirect.com/science/article/B73DX-4HTBM2H-1/2/a934fe9db7f671cf3ce96c4c7d729ef0

Gomez-Diaz RA, Martinez-Hernandez AJ, Aguilar-Salinas CA, Violante R, Alarcon ML, Villarruel MJ, Rodarte NW-, Solorzano-Santos F. 2005. Percentile distribution of the waist circumference among Mexican pre-adolescents of a primary school in Mexico City. Diabetes, Obes Metab [Internet] 7:716–721. Available from: http://doi.wiley.com/10.1111/j.1463-1326.2004.00461.x

Granados A, Gebremariam A, Lee JM. 2015. Relationship between timing of peak height velocity and pubertal staging in boys and girls. J Clin Res Pediatr Endocrinol 7:235–237.

Ibáñez L, Jiménez R, de Zegher F. 2006. Early Puberty-Menarche After Precocious Pubarche: Relation to Prenatal Growth. Pediatrics [Internet] 117:117–121. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16396868%5Cnhttp://pediatrics.aappublications.org/cgi/doi/10.1542/peds.2005-0664

Jansen EC, Herran OF, Villamor E. 2015. Trends and correlates of age at menarche in Colombia: Results from a nationally representative survey. Econ Hum Biol 19:138–144.

Kaestle CE, Halpern CT, Miller WC, Ford CA. 2005. Young age at first sexual intercourse and sexually transmitted infections in adolescents and young adults. Am J Epidemiol [Internet] 161:774–80. Available from: http://www.ncbi.nlm.nih.gov/pubmed/15800270

Kaplowitz P, Bloch C. 2015. Evaluation and Referral of Children With Signs of Early Puberty. Pediatrics [Internet] 137:1-NaN-6. Available from: http://pediatrics.aappublications.org/content/137/1/1.58?utm_source=highwire&utm_medium=email&utm_campaign=Pediatrics_etoc

Kelly A, Winer KK, Kalkwarf H, Oberfield SE, Lappe J, Gilsanz V, Zemel BS. 2014. Age-Based Reference Ranges for Annual Height Velocity in US Children. J Clin Endocrinol Metab [Internet] 99:2104–2112. Available from: http://press.endocrine.org/doi/10.1210/jc.2013-4455

Krieger N, Kiang M V., Kosheleva A, Waterman PD, Chen JT, Beckfield J. 2015. Age at menarche: 50-year socioeconomic trends among US-born black and white women. Am J Public Health 105:388–397.

Lagranja ES, Phojanakong P, Navarro A, Valeggia CR. 2014a. Indigenous populations in transition: An evaluation of metabolic syndrome and its associated factors among the Toba of northern Argentina. Ann Hum Biol [Internet] 4460:1–7. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25004443

Lagranja ES, Valeggia CR, Navarro A. 2014b. Prácticas alimentarias y actividad física en adultos de una población Toba de la provincia de Formosa, Argentina. Diaeta [Internet] 32:35–41. Available from: http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1852-73372014000100006&lng=es&nrm=iso&tlng=es

Lear S, James P, Ko G, Kumanyika S. 2010. Appropriateness of waist circumference and waist-to-hip ratio cutoffs for different ethnic groups. Eur J Clin Nutr 64:42–61.

Lejarraga H, Del Pino M, Fano V, Caino S, Cole TJ. 2009. Referencias de peso y estatura desde el nacimiento hasta la madurez para niñas y niños argentinos . Incorporación de datos de la OMS de 0 a 2 años , recálculo de percentilos para obtención de valores LMS. Arch Argent Pediatr 107:126–133.

Lewitt MS, Baker JS, Mooney GP, Hall K, Thomas NE. 2012. Pubertal stage and measures of adiposity in British schoolchildren. Ann Hum Biol 39:440–447.

Liebert MA, Snodgrass JJ, Madimenos FC, Cepon TJ, Blackwell AD, Sugiyama LS. 2013. Implications of market integration for cardiovascular and metabolic health among an indigenous Amazonian Ecuadorian population. Ann Hum Biol 40:228–242.

Maffeis C, Banzato C, Talamini G. 2008. Waist-to-Height Ratio, a Useful Index to

Identify High Metabolic Risk in Overweight Children. J Pediatr 152.

Magalhães EI da S, Sant'Ana LF da R, Priore SE, Franceschini S do CC. 2014. Waist circumference, waist/height ratio, and neck circumference as parameters of central obesity assessment in children. Rev Paul Pediatr [Internet] 32:273–81. Available from: http://dx.doi.org/10.1016/S2359-3482(15)30022-1

Marrodán MD, Martínez-Álvarez JR, González-Montero De Espinosa M, López-Ejeda N, Cabañas MD, Prado C. 2013. Diagnostic accuracy of waist to height ratio in screening of overweight and infant obesity. Med Clin (Barc) [Internet] 140:296–301. Available from: http://www.ncbi.nlm.nih.gov/pubmed/22726769

Marván ML, Catillo-López RL, Alcalá-Herrera V, Callejo D del. 2016. The Decreasing Age at Menarche in Mexico. J Pediatr Adolesc Gynecol:1–4.

Monteiro CA, Conde WL, Lu B, Popkin BM. 2004. Obesity and inequities in health in the developing world. Int J Obes Relat Metab Disord 28:1181–1186.

Obeidallah DA, Brennan RT, Brooks-Gunn J, Kindlon D, Earls F. 2000. Socioeconomic Status, Race, and Girls' Pubertal Maturation: Results From the Project on Human Development in Chicago Neighborhoods. J Res Adolesc [Internet] 10:443–464. Available from: http://www.leaonline.com/doi/abs/10.1207%2FSJRA1004_04

Olmedo SI, B.S, Valeggia C, M.D. 2014. The initiation of complementary feeding among Qom indigenous people. 112:9–13.

de Onis M, Onyango A, Borghi E, Siyam A, Nishida C, SIekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 85:661–668.

Orden AB, Vericat A, Apezteguia MC. 2011. Age at menarche in urban Argentinian girls: association with biological and socioeconomic factors. Anthropol Anzeiger 68:309–322.

Ossa X, Bustos P, Munoz S, Amigo H. 2012. Age at menarche and indigenous ancestry. A population study in Chile. Rev Med Chil [Internet] 140:1035–1042. Available from: http://www.scielo.cl/pdf/rmc/v140n8/art10.pdf%5Cnhttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed11&NEWS=N&AN=23282777

Ossa XM, Munoz S, Amigo H, Bangdiwala SI. 2010. Secular trend in age at menarche in indigenous and nonindigenous women in Chile. Am J Hum Biol 22:688–694.

Parent AS, Teilmann G, Juul A, Skakkebaek NE, Toppari J, Bourguignon JP. 2003. The Timing of Normal Puberty and the Age Limits of Sexual Precocity: Variations around the World, Secular Trends, and Changes after Migration. Endocr Rev 24:668–693.

Pizzi C, Cole TJ, Corvalan C, Silva I dos S, Richiardi L, De Stavola BL. 2014. On modelling early life weight trajectories. J R Stat Soc Ser A Stat Soc 177:371–396.

Rigon F, Bianchin L, Bernasconi S, Bona G, Bozzola M, Buzi F, Cicognani A, De Sanctis C, De Sanctis V, Radetti G, Tatò L, Tonini G, Perissinotto E. 2010. Update on Age at Menarche in Italy: Toward the Leveling Off of the Secular Trend. J Adolesc Heal [Internet] 46:238–244. Available from: http://dx.doi.org/10.1016/j.jadohealth.2009.07.009

Rogol AD, Clark PA, Roemmich JN. 2000. Growth and pubertal development in children and adolescents : effects of diet and physical activity 1 – 4. Am J clinal Nutr 72:521S–528S.

Rosinger A, Tanner S, Leonard WR. 2013. Precursors to overnutrition: The effects of household market food expenditures on measures of body composition among Tsimane’ adults in lowland Bolivia. Soc Sci Med [Internet] 92:53–60. Available from: http://dx.doi.org/10.1016/j.socscimed.2013.05.022

Sant’Anna M, Tinoco A, Rosado L, Sant’Ana L, Brito I, Araujo L. 2010. Effectiveness of the conicity index and waist to height ratio to predict the percentage of body fat in children. Nutr Rev Soc Bras Alim Nutr:67–80.

Shaik SA, Hashim RT, Alsukait SF, Abdulkader GM, AlSudairy HF, AlShaman LM, Farhoud SS, Fouda Neel MA. 2015. Assessment of age at menarche and its relation with body mass index in school girls of Riyadh, Saudi Arabia. Asian J Med Sci [Internet] 7:5. Available from: http://www.nepjol.info/index.php/AJMS/article/view/13439

Stöckl D, Meisinger C, Peters A, Thorand B, Huth C, Heier M, Rathmann W, Kowall B, Stöckl H, Döring A. 2011. Age at menarche and its association with the metabolic syndrome and its components: Results from the Kora F4 study. PLoS One 6.

Stoll BA. 1998. Western diet, early puberty, and breast cancer risk. Breast Cancer Res Treat [Internet] 49:187–193. Available from: http://link.springer.com/10.1023/A:1006003110909

Tanner J. 1989. Fetus into man: physical growth from conception to maturity. Cambridge, MA: Harvard University Press.

Tanner J, Davies P. 1985. Clinical longitudinal standards for height and height velocity for North American children. J Pediatr 107:317–329.

Torres M, Luis M, Cesani M, Luna M, Castro L, Quintero F, Oyhenart E. 2011. Comparative analysis of growtha nd sexual maturation in girls of Santa Rosa (La Pampa) and La Plata (Buenos Aires), Argentina. Arch Latinoam Nutr 61:36–44.

Urlacher SS, Blackwell AD, Liebert M a., Madimenos FC, Cepon-Robins TJ, Gildner TE, Snodgrass JJ, Sugiyama LS. 2015. Physical growth of the shuar: Height, Weight, and BMI references for an indigenous amazonian population. Am J Hum Biol [Internet] 0:n/a-n/a. Available from: http://doi.wiley.com/10.1002/ajhb.22747

Urlacher SS, Liebert MA, Snodgrass JJ, Blackwell AD, Cepon-Robins TJ, Gildner TE, Madimenos FC, Amir D, Bribiescas RG, Sugiyama LS. 2016. Heterogeneous effects of market integration on subadult body size and nutritional status among the Shuar of Amazonian Ecuador. Ann Hum Biol [Internet] in press:316–329. Available from: http://www.tandfonline.com/doi/full/10.1080/03014460.2016.1192219

Valeggia C, Ellison PT. 2003a. Lactational amenorrhoea in well-nourished toba women of Formosa, Argentina. J Biosoc Sci [Internet] 0:1–23. Available from: http://www.journals.cambridge.org/abstract_S0021932003006382

Valeggia CR, Burke KM, Fernandez-Duque E. 2010. Nutritional status and socioeconomic change among Toba and Wichí populations of the Argentinean Chaco. Econ Hum Biol [Internet] 8:100–10. Available from: http://www.ncbi.nlm.nih.gov/pubmed/19959406

Valeggia CR, Ellison PT. 2003b. Impact of breastfeeding on anthropometric changes in peri-urban Toba women (Argentina). Am J Hum Biol [Internet] 15:717–24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/12953184

Valeggia CR, Tola F. 2003. Argentine Toba. Encycl Med Anthropol 2:564–572.

Walker R, Gurven M, Hill KIM, Migliano A, Chagnon N, Souza RDE, Djurovic G, Hames R, Hurtado AM, Kaplan H, Kramer K, Oliver WJ, Valeggia C, Yamauchi T. 2006. Growth Rates and Life Histories in Twenty-Two Small-Scale Societies. Am J Hum Biol 311:295–311.

Wehkalampi K, Hovi P, Dunkel L, Strang-Karlsson S, Järvenpää AL, Eriksson JG, Andersson S, Kajantie E. 2011. Advanced pubertal growth spurt in subjects born preterm: The helsinki study of very low birth weight adults. J Clin Endocrinol Metab 96:525–533.

Yan W, Bingxian H, Hua Y, Jianghong D, Jun C, Dongliang G, Yujian Z, Ling L, Yanying G, Kaiti X, Xiaohai F, Da M. 2007. Waist-to-Height Ratio is an Accurate and Easier Index for Evaluating Obesity in Children and Adolescents*. Obesity [Internet] 15:748–752. Available from: http://doi.wiley.com/10.1038/oby.2007.601

Yan W, Yao H, Dai J, Cui J, Chen Y, Yang X, Harshfield GA, Wang X. 2008. Waist circumference cutoff points in school-aged Chinese Han and Uygur children. Obesity (Silver Spring) 16:1687–1692.

Table 1. Number of participants entering and exiting study and total observed per study year.

| Study Year | Recruited | Exited Study | Total Followed/Yr |
|---|---|---|---|
| | n | n | n |
| 2011 | 41 | 2 | 41 |
| 2012 | 16 | 10 | 55 |
| 2013 | 4 | 22 | 49 |
| 2014 | | 15 | 27 |
| 2015 | | 12 | 12 |

**Table 2**. Descriptive statistics of nutritional & developmental markers at menarche, among participants with known age at menarche (n = 51 out of 61 original participants).

| | Range | Mean ± SD | Median (IQR) |
|---|---|---|---|
| Age (yrs) | 9.6 – 13.8 | 11.5 ± 0.9 | 11.3 (10.9 - 11.9) |
| Height (cm) | 136 – 157 | 146.7 ± 6.7 | 147 (143 – 151) |
| Weight (kg) | 29.3 – 100.7 | 44.5 ± 11.2 | 41.2 (38.1 – 46.9) |
| BMI (kg/m$^2$) | 15.6 – 40.9 | 20.6 ± 4.3 | 20.0 (17.9 – 21.5) |
| HAZ (WHO)[a] | -2.34 – 2.49 | -0.12 ± 1.05 | -0.11 (-0.71 – 0.33) |
| HAZ (Argentina)[b] | -0.89 – 3.61 | 0.89 ± 1.00 | 0.84 (0.33 – 1.29) |
| WAZ (Argentina)[b] | -1.71 – 4.73 | 1.02 ± 1.25 | 1.16 (0.31 – 1.50) |
| BMIZ (WHO)[a] | -1.98 – 4.64 | 0.83 ± 1.22 | 0.93 (0.22 – 1.45) |
| Body fat % | 13 – 52 | 20.6 ± 6.9 | 25 (22 – 30) |
| Waist circ. (cm) | 59 – 112 | 70.0 ± 8.8 | 69 (64 – 73) |
| Hip circ. (cm) | 68 – 118 | 78.3 ± 8.3 | 76 (73 – 82) |
| Chest circ. (cm) | 60 – 119 | 78.5 ± 8.6 | 76.5 (75 – 119) |
| Bicep circ. (cm) | 17 – 37 | 23.1 ± 3.2 | 23 (21 – 25) |
| Waist/height ratio | 0.39 – 0.71 | 0.48 ± 0.05 | 0.48 (0.44 – 0.50) |
| Waist/hip ratio | 0.79 – 0.97 | 0.89 ± 0.04 | 0.89 (0.87 – 0.92) |
| Subscapular skinfold (mm) | 6.7 – 28.3 | 14.5 ± 4.9 | 13.5 (11.0 – 16.8) |
| Tricep skinfold (mm) | 6.7 – 25.0 | 13.3 ± 4.7 | 12.0 (10.0 – 25.0) |

[a]WHO 2007 standards were used to calculate height-for-age (HAZ) and BMI-for-age (BMIZ) z scores. [b]Argentina 2009 pediatric growth references used to calculate HAZ and weight-for-age z scores (WAZ).

**Table 3.** Prevalence of thinness, overweight, obese, and short stature among participants at first observation (n = 61) and at first report of menarche (n = 51).

| | First observation | At menarche |
|---|---|---|
| BMIZ cut-off | | |
| Thinness (< - 2 SD) | 2 (3%) | 0 (0%) |
| Overweight (> 1 SD) | 16 (26%) | 17 (33%) |
| Obese (> 2 SD) | 5 (8%) | 6 (12%) |
| HAZ < -2SD | 4 (7%) | 1 (2%) |

BMIZ, HAZ, and cut-offs calculated from WHO (2007) standards and guidelines.

## Figure Captions

**Figure 1.** Age at menarche survival curve for Qom girls estimated from 61 subjects (n events = 51, n censored subjects = 10). The graph depicts the Kaplan-Meier survival function (black line) with 95% of confidence interval (grey band), and median survival (dashed horizontal and vertical lines)

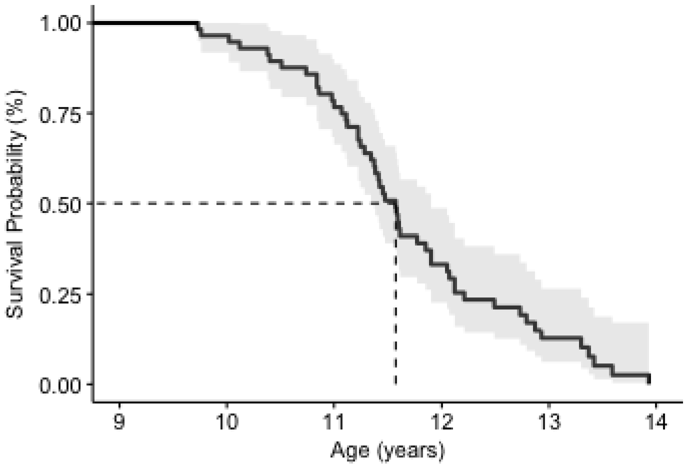
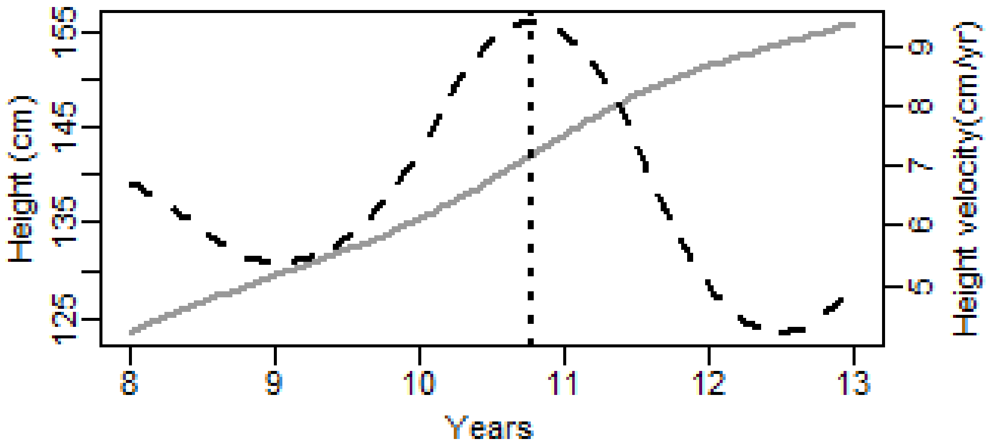
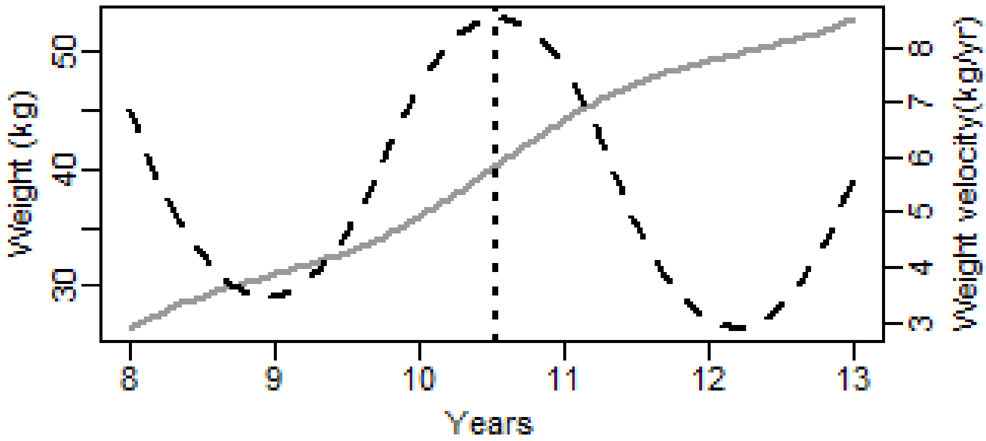
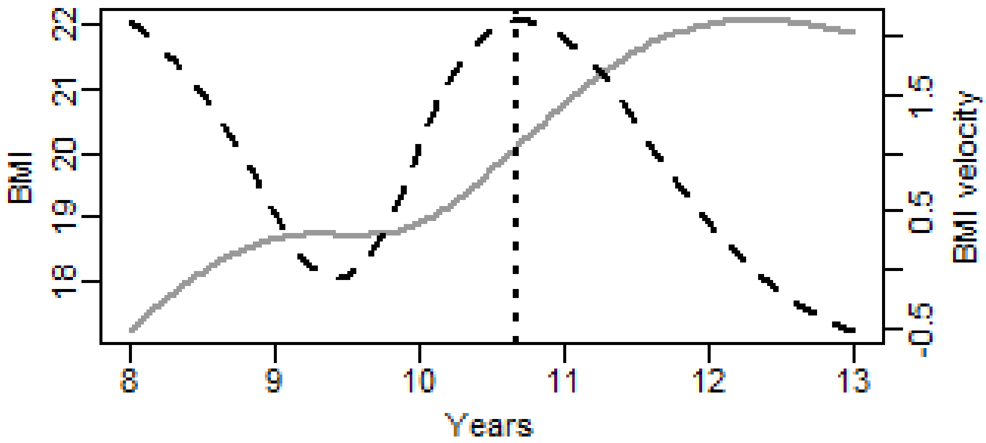



**Figure 2 A-C.** SITAR models of age at peak growth velocity, APGV (black dashed line), and peak velocity, PV (solid grey line), for (A) height (APGV = 10.8 years, PV = 9.4 cm/year), (B) weight (APGV = 10.5 years, PV = 8.5 kg/year, and (C) BMI (APGV = 10.7 years). Models were estimated from 1174 and 1171 observations, respectively, for height and weight/BMI from 58 Qom girls ages 8 – 13.


Height (cm)
125
135
145
155
Height velocity(cm/yr)
5
6
7
8
9
8
9
10
11
12
13
Years


Weight (kg)
30
40
50
Weight velocity(kg/yr)
3
4
5
6
7
8
8
9
10
11
12
13
Years


BMI
18
19
20
21
22
BMI velocity
-0.5
0.5
1.5
8
9
10
11
12
13
Years