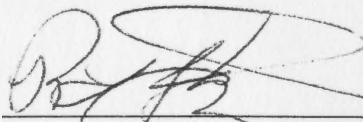


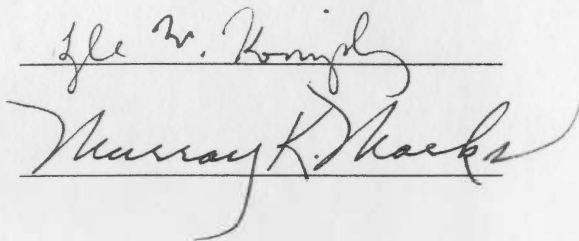
To the Graduate Council:

I am submitting herewith a thesis written by Kathryn A. King entitled "Developing Stature Estimation Regression Formulae for the Arikara of the Larson and Leavenworth Sites." I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

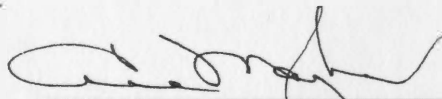


Richard L. Jantz, Major Professor

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recommend its acceptance:



Acceptance for the Council:



Vice Provost and Dean of
Graduate Studies

**Developing Stature Estimation Regression Formulae
For the Arikara of the Larson and Leavenworth Sites**

**A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville**

**Kathryn A. King
December 2002**

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Abstract

Stature is an important descriptive characteristic of an individual. Living stature cannot be measured directly in archaeological populations and thus must be estimated by bone. Current stature estimation formulae cannot be used with archaeological populations because the relationships between stature and the length of the various bones used in estimation differ among races and populations. Similarly, secular change in stature makes the use of formulae derived from modern populations on archaeological groups problematic.

Anatomical methods of estimating stature account for the skeletal elements that contribute to an individual's height and provide an estimate of the soft tissue component of stature. These methods give results very close to properly recorded living statures. In populations for which recorded statures or cadaver lengths are unavailable, anatomically estimated statures can be substituted for living statures for the purpose of creating stature estimation formulae.

Living stature was estimated for 48 individuals (25 females, 23 males) excavated from the South Dakota Larson (39WW2) and Leavenworth (39CO9) sites using Fully's anatomical method. These sites represent two Arikara villages from the Great Plains protohistoric and historic phases, respectively. The Fully method estimates were treated as living statures for the purpose of regression. Linear regression formulae were calculated using the Fully estimates and basion-bregma height, bicondylar length of the femur, condylo-malleolar length of the tibia, vertebral column height, height of the articulated talus, and calcaneus, maximum humerus length, and maximum radius length.

The regression formulae were calculated in two ways. In the first manner, classical calibration, the bone or bones are regressed onto stature and the equation is solved for stature. This method creates general formulae that should be applicable to many American Indian and other indigenous American populations. In the second manner, inverse calibration, stature is regressed onto the bone or bones. This method ideally gives more precise but population specific formulae.

To illustrate the importance of population specificity, the long bone measurements for the Arikara were used in stature estimation formulae developed from closely related groups including Illinois Middle Mississippians, Ohio Valley natives from the archaic through protohistoric periods, modern Mesoamericans, and modern "Mongoloid" and Mexican populations.

The goals of this study are 1) to develop population specific formulae for use in estimating stature in incomplete skeletal remains of the Arikara and closely affiliated groups; 2) to develop general stature estimation formulae for potential use in other indigenous America groups; and 3) to argue for the importance of using population specific formulae when estimating stature.

The results of this study show that for this population, the best estimator of living stature in females is bicondylar femur length, followed closely by the combined femur and tibia lengths. For males, the best estimator was the combination of the femur and tibia lengths with the next best estimator being femur length alone. In both sexes the vertebral column and humerus and radius estimate well. Basion-bregma height did not work at all in females and only marginally in males. Articulated talus-calcaneus height produced regression formulae of questionable utility.

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Chapter I

Introduction and Literature Review

The ability to accurately estimate living stature is important in both forensic anthropology and skeletal biology. Good estimates of living stature assist in the identification of skeletal remains by narrowing the pool of missing persons to those whose stature is close to the estimate derived from the bones present. Stature is also a useful descriptor of an archaeological population (Boldsen 1984). Because it is a complex trait that is affected by both genetics and environment, knowledge about a population's stature can provide insight about biology, subsistence, disease, growth and development, and environmental stressors. Additionally, knowing how the distribution of stature varies among generations of a population can help to explain the affects of environmental or cultural changes documented in the archaeological record.

The most common method for estimating living stature in modern populations is to measure the long bones, typically the femur, tibia, humerus and radius, and insert these values into regression formulae developed from specific reference populations. Separate formulae are derived for each sex to account for dimorphism and the differing proportions of long bones to stature (Olivier et al. 1978).

Population specificity should also be considered due to the differing relationships between long bones and stature among populations (Genovés 1967). These differences make panhuman formulae impractical to use because of the large standard errors necessary to account for all stature variation among humans (Neumann and Waldman 1967). Anthropologists who worked with multiracial samples typically subdivided them

into sub-samples according to ancestry (Feldesman and Lundy 1988, Feldesman and Fountain 1996). However, Feldesman and Fountain (1996) caution that it can be problematic to divide the human population into black, white, and Asian/American Indian, the three commonly used “mega-races”, due to substantial variation within these divisions. Though subdividing humans into ancestral groups gives narrower confidence intervals than panhuman formulae, formulae which designate all humans as either black, white, or Asian/American Indian give estimates that are still too broad to be of much practical use (Feldesman and Fountain 1996).

The most accurate formulae are those derived from distinct populations. These formulae give precise stature estimates for the populations for which they were designed, but are not largely applicable to other groups. Many authors report inaccurate or biased results from applying regression formulae developed from one population to another group (Olivier et al. 1978, Trotter and Gleser 1952, Sciulli et al. 1990, Jason and Taylor 1995). Still more caution against using inappropriate formulae to estimate stature and advocate developing stature estimation formulae specific to a particular population (Feldesman and Fountain 1996, Feldesman and Lundy 1988, Neumann and Waldman 1967, Stevenson 1929, Lundy 1985).

Several studies demonstrate temporal variation within closely related biological populations seems to be insignificant in reference to the proportion of long bones to stature. Huber and Jowett (1969) report that a Medieval German population has similar long bone to stature proportions as Trotter and Gleser’s (1952) sample of American whites. Sciulli and Giesen (1993) report that despite changes in the mean stature

throughout time, the body proportions of American Indians found in present-day Ohio and the Ohio Valley region are consistent from the Late Archaic to protohistoric.

The most commonly used regression formulae for estimating stature in modern groups are those created by Mildred Trotter and Goldine Gleser (1952, 1958). These formulae typically work well for American whites and blacks, but are problematic to use with American Indian populations. Trotter and Gleser never derived equations specifically for American Indians, but included them in a catchall group they called "Mongoloid". This group is composed of 23 Japanese, 22 American Indians, 20 Filipinos, nine Hawaiians, two Chinese, two Samoans, one Mayalan, and 13 of mixed white and Mongoloid ancestry (Trotter and Gleser 1958). The Mongoloid group includes individuals from or with ancestors from two continents and four island groups, making it the most geographically diverse of Trotter and Gleser's study. Because of the immense amounts of variation in stature and body proportions within the Mongoloid group, these formulae are typically not successful at estimating stature in American Indians.

Takamura et al.(1988) estimates the average leg length/stature ratio of Japanese male medical students for the years 1961 to1986 to be .4544, while the approximate leg length/stature ratio for the Arikara males, is .5440, a figure that does not account for the cartilage of the knee and other soft tissues of the leg that would make this ratio higher.

The only other group in Trotter and Gleser's 1958 study that might be of use for estimating stature in American Indians is the Mexican group. However, this group likely does not represent a group of indigenous peoples due to varying degrees of mixed ancestry common in the Hispanic world (Lisker et al. 1990).

Stature estimation formulae have been derived from other prehistoric and modern populations indigenous to the Western hemisphere, including modern Mesoamericans (Genovés 1967), prehistoric Ohioans (Sciulli et al. 1990, Sciulli and Giesen 1993), and a group of Middle Mississippians from Dickson Mound in Illinois (Neumann and Waldman 1967). These formulae may work for other indigenous American groups, a possibility that will be tested by this research. However, these formulae were designed to be specific to the populations from which they are derived. Neumann and Waldman (1967) and Sciulli et al. (1990) suggest that their formulae may work for other American Indian groups if they possess similar body proportions to the reference samples, but also argue that the reconstruction of stature is best done using formulae developed from the population being studied.

Two pieces of information are necessary for the development of regression formulae for predicting stature: 1) an accurate estimate of living stature and 2) the measurements of the skeletal elements one wants to relate to stature (Neumann and Waldman 1967). It should be noted that stature is not a static property of an individual even after maximum adult stature is attained. Trotter and Gleser argue that adults over the age of 30 decrease in stature at an average rate of .06cm per year due to the loss of bone mass and the thinning of soft tissues (1952), although other studies demonstrate that stature begin to decrease in the mid 40s and accelerates as an individual grows older (Cline et al. 1989, Galloway et al. 1990). This decrease in stature can lead to an older-aged individual being significantly shorter than he or she was at their maximum height. Additionally, an individual's stature may fluctuate within the course of a day due to the compression of the intervertebral discs and other cartilaginous structures under the load

of the body's weight. Thus, any measure of stature can be considered an approximation; a measurement taken at midnight will differ from one taken immediately upon waking, and a measurement of maximum stature on an elderly person will not accurately reflect that individual's maximum stature in early adulthood.

The measurements used in stature regression formulae are typically taken on dry bones using standard osteological equipment (i.e., osteometric board, sliding and spreading calipers), although some studies have been conducted using radiographs (Musgrave and Harneja 1978), or wet bone lengths, including cartilage, measured while the bones are in the cadavers (De Mendonca 2000). One advantage of using dry bones in regression formulae is that the measurements taken on them are straightforward and easy to replicate. Additionally, formulae created using dry bone measurements are more practical for use in archaeological contexts where remains are typically skeletonized.

Living stature can be estimated in several ways. Snow and Williams (1971) caution against using recorded heights, citing the case of an individual with extensive police and medical records which give ranges of 62 to 67 inches and 64 to 66 inches respectively. However, they support the use of recorded statures found in military medical records. These records are usually accurate, probably due to written regulations governing the measurement of stature (Snow and Williams 1971). Trotter and Gleser used statures from military records for positively identified World War II and Korean War casualties (1952, 1958), as did Lundy, who used similar records for three naval aviators who were killed in action during the Vietnam War (1988a).

De Mendonca used cadaver length as an estimate of living stature (2000). The cadavers in this study were measured while they were lying horizontally on a table.

Cadaver lengths measured horizontally are generally greater than the individual's living stature due to the lack of pressure on the cartilaginous tissues that normally affect vertical stature measurements and the relaxation of the normal curvature of the spine. To account for these differences, De Mendonca subtracted 2 cm from the cadaver length to account for this lack of compression and which he argues will better approximate living statures.

The lack of recorded statures makes estimating stature in historic or prehistoric populations more difficult. The statures of modern American Indians cannot be used because of the documented secular change of stature in Americans during the past two centuries that more than likely applies to American Indian groups (Meadows Jantz 1996). Although Prince (1989) found no conclusive evidence for secular change in several Sioux populations, this study focused on effects of the transition from traditional lifeways to reservation life and only includes adults with birth years ranging from 1820 to 1880. While Prince's findings are significant, they do not represent a contemporaneous American Indian population. Also, a significant degree of admixture is frequently found in modern American Indian groups. These groups tend to be defined culturally or politically rather than by ancestry, with some groups requiring only 1/32 American Indian ancestry for membership. Other groups place no minimum ancestry requirement, only documentation that the individual has one American Indian ancestor (Thornton 1997).

One method used to estimate stature in the absence of recorded statures is measuring grave lengths during excavation (Neumann and Waldman 1967). While this does provide an accurate representation of the length of the vertebral column, it can be

problematic if the elements have been disturbed, if the cranium rolls during excavation, or if the individual was buried in a flexed position.

For a skeletonized sample for which living statures or cadaver lengths are unavailable, stature can be estimated using anatomical methods. These measurements account for the skeletal elements that contribute to height and provide an estimate of the contribution of soft tissue to height. Anatomical estimates are generally very accurate and can be used as part of stature estimation regression formulae (Lundy 1985).

Anatomical stature can be measured by arranging the skeletal elements from the cranium to calcaneus in superior to inferior order, leaving spaces to account for the intervertebral discs and other soft tissues. The skeleton is then measured from bregma to the bottom of the calcaneus. However, this method is rather cumbersome and requires the careful positioning of skeletal elements.

Georges Fully (1960) streamlined the anatomical method of measuring stature. His method allows the observer to measure each element individually, eliminating the need for the meticulous positioning of all of the bones that anatomically contribute to stature. Fully's method also allows for the estimation of missing vertebrae, a significant advantage to have when working with archaeological populations (Lundy 1988b). It is easily applicable to well preserved skeletal collections where the long bones, cranium, and the majority of the vertebrae are complete and not damaged in any way that compromises the necessary measurements.

Fully devised this method in 1955 when the French Ministry of Former Combatants and Victims of War charged him with the medicolegal examination and identification of individuals from the Mauthausen and Gusen concentration camps. Some

of the individuals were interred with metal or leather identity bracelets that were used to establish positive identifications. Fully's sample consisted of 3165 white males whose living statures had been recorded by the military or by the SS upon arrival at the concentration camps (Fully 1956).

There are a few flaws with the Fully method. The largest caveat is that it is only useful for nearly complete skeletons (Lundy 1988b). The heights of missing vertebrae can be estimated provided that the absent vertebrae comprise 20 percent or less of the total height of the vertebral column (Sciulli et al. 1990). Another problem is that this method has not been widely tested using other populations or females. If there are population or sex differences in the contribution of soft tissues to height, they are, as of yet, undocumented. Byers (2002) argues that soft tissue differences among races are probably minimal and thus Fully's anatomical method should be applicable to all populations. Byers also states that because females are dimensionally about 92% of males, their soft tissue correction factor should be reduced to 92% of the values determined by Fully. Byers gives no citation for this reduction and no further explanation of its origin. Until proven otherwise, there is no information justifying that a male and a female with identical skeletal heights should have different amounts of soft tissue.

Despite some gaps in the knowledge of its applicability to other populations and females, the Fully method is generally considered to be the most accurate estimator of living stature in skeletal populations (Snow and Williams 1971). This method usually produces small amounts of error. In Fully's original study he found that this method predicted stature within 2cm of the recorded height in 83.33 percent of the cases. No

difference between recorded stature and Fully's estimate was greater than 3.5cm (Fully 1956).

The Fully method has been tested using three complete skeletons of United States servicemen who were casualties of the Vietnam War. The individuals were positively identified by dental records. In these three cases the Fully method was equally or more accurate than estimates from Trotter and Gleser's regression formulae (Lundy 1988b).

Another test of the Fully method addresses the issue of the potential population specificity of the original soft tissue correction. Feldesman and Lundy (1988) found that for a sample of 175 South African black males, the mean difference between corrected cadaver length and estimates made using the Fully method was .131cm, signifying that Fully's method produced more accurate estimates for this population than on Fully's original sample. Fully and Pineau's (1960) test of the Fully method reveal consistent disparities of less of 2cm. El-Najjar and McWilliams (1978) report a standard deviation of 2.05cm for the Fully method.

There are numerous studies devoted to various mathematical methods for predicting stature from a single bone or a combination of bones. While some studies utilize ratios between the length of a long bone and living stature (Feldesman and Fountain 1996), the most common method is linear regression. Linear regression establishes a relationship between two variables and gives formulae that can be used to estimate the value of one variable given the value of the other. This method was used by Trotter and Gleser in their 1952 and 1958 papers and has dominated the stature estimation literature since.

The maximum and physiological lengths of many bones have been examined for their utility in predicting stature. The most commonly used elements are the femur, tibia, humerus, and radius (Trotter and Gleser 1952, Genovés 1967, Sciulli et al. 1990, Feldesman and Lundy 1988), although regression formulae have also been developed for the physiological lengths of the metacarpals (Musgrave and Harneja 1978), the maximum length of the talus and the maximum and posterior lengths of the calcaneus (Holland 1995), and the complete and segmented lengths of the vertebral column (Sciulli et al. 1990, Jason and Taylor 1995, Feldesman and Lundy 1988).

Statures estimated from lower limb bones often have smaller standard errors than those estimated from upper limb bones. This is most likely because the lower limb bones directly contribute to stature, but the upper limb bones, while still highly correlated to stature, do not (Trotter and Gleser 1952). The femur and tibia typically give the best results for individual bones (Feldesman and Lundy 1988, Genovés 1967, Trotter and Gleser 1952). The overall most accurate regression formulae using multiple bones are those incorporating the femur and tibia (Trotter and Gleser 1952, Feldesman and Lundy 1988, Sciulli et al. 1990), some of which include the lumbar vertebrae. While the inclusion of the lumbar vertebrae often increases the accuracy of these formulae, these formulae are less practical to use in many forensic and archaeological contexts where some of the vertebrae may be damaged or missing (Feldesman and Lundy 1988).

Chapter II

The Collection

The individuals used in this study are from the Plains Collection curated at the University of Tennessee. This collection consists of remains from four cemeteries, Larson (39WW2), Leavenworth (39CO9), Mobridge (39WW1), and Sully (39SL4), which were excavated under the direction of William M. Bass (Owsley and Jantz 1994).

The history of the Arikara can be traced to the Central Plains tradition, the most recent tradition in this region that lacks evidence of European contact. Sites in this tradition are marked by isolated farmsteads and small villages composed of square-shaped earthlodges with rounded corners. The people who inhabited these sites left large assemblages of artifacts, indicating that these sites were occupied for long periods of time (Blakeslee 1994). Central Plains sites are found in east and south-central Nebraska, western Iowa, and northern Kansas. This tradition is associated with the Caddoan language family that includes the dialects of the Arikara and the Pawnee (Meyer 1977) as well as groups in Oklahoma, Arkansas, Texas, and Louisiana (Blakeslee 1994).

Some time before the start of the protohistoric era, all or part of the Central Plains groups migrated north to northern Nebraska and the Upper Missouri River region of South Dakota. This movement marks the beginning of the Initial Coalescent period. These sites differ from Central Plains sites in the circular shape of the earthlodges, evidence of increased warfare with neighboring groups, and stylistic differences in tools and ceramics (Blakeslee 1994).

The Initial Coalescent was followed by the Extended Coalescent period, marked by the wider spacing of earthlodges within the villages. Extended Coalescent villages are unfortified with the exception of villages on the northern periphery of the territory, which included a central fortified area to which individuals living in these dispersed settlements could go to for protection (Blakeslee 1994).

Early encounters with fur traders provide ethnohistoric data about the Postcontact Coalescent Arikara. They were horticulturalists who also engaged in seasonal buffalo hunts. Staples of the Arikara diet include corn, squash, beans, and buffalo meat (Meyer 1977) which were prepared in earthenware vessels. The Arikara also cultivated tobacco. Subsistence-oriented labor was divided along sex lines, with women tending the crops while men engaged in sporadic but dangerous buffalo hunts. The elderly worked as long as they were capable, then spent their time educating the young about tribal customs (Meyer 1977).

Unlike some Plains groups, the Coalescent period Arikara rarely practiced scaffold burials. In scaffold burials, the postcranial bones were interred along a riverbank once decomposition was complete while the cranium was brought back to the village. Instead, the Arikara typically buried their dead in cemeteries. Individuals were usually painted and dressed before interment (Meyer 1977).

This study focuses on the Larson and Leavenworth sites due to the large number of complete and mostly complete skeletons excavated at these sites. Both are located along the Missouri River in northern South Dakota, with Larson, the earlier of the two sites, being somewhat downriver. The Larson site was occupied approximately from 1679 to 1732 (Kelley et al. 1994). It falls under the protohistoric era of the Postcontact

Coalescent, meaning that European artifacts were found at this site but there is no historical documentation of Europeans visiting this settlement. The site is classified as part of the Le Beau phase of the Postcontact Coalescent variant and was likely partially ancestral to the individuals of the Leavenworth site (Blakeslee 1994).

During the early historic period there were an estimated 9,000 to 24,000 individuals living in 32 Arikara villages. Several smallpox epidemics hit these villages in the middle to late 18th century, drastically reducing the population. Some of the survivors of the epidemics united to form a new village, now known as the Leavenworth site (Meyer 1977). Leavenworth was occupied approximately from 1802 until 1832 (Kelley et al. 1994) with an estimated population of 2500 near the end of its occupation (Meyer 1977). A diversity of ceramic types, linguistic, ethnohistorical, and biological data indicate that the site was occupied by individuals representing two protohistoric phases, Le Beau and Bad River (Byrd and Jantz 1994), meaning that the Leavenworth site is probably more biologically diverse than the Larson site.

Chapter III

Materials and Methods

A. Demographics of the Sample

Forty-eight individuals were used in this study. The sample is composed of 21 females and 16 males from the Larson site and four females and seven males from the Leavenworth site (males N=23, females N=25). The ages of the individuals in this study range from approximately 18 years to over 41 years old. Individuals were included if the apophyses were completely fused to the vertebral bodies and if there were no degenerative changes affecting the length or heights of any element. See table 1, this page.

Individuals who possessed obvious pathologies that affected stature (kyphosis of the spine, extensive degeneration of the vertebral bodies, etc.) were not included in this study. The presence of vertebral osteophytes did not preclude inclusion in this study as they typically occurred on the dorsal-ventral plane and did not alter the anterior height of the vertebra. One case involved an osteophyte on the odontoid process of the second cervical vertebra. In this case the osteophyte was avoided by measuring the height of the vertebra from the side.

Table 1. Sex Distribution by Age

	18-30 years	31-40 years	over 41 years
Females (N=25)	16	9	0
Males (N=23)	7	13	3

B. The Fully Method

Anatomical stature was estimated using the Fully method. The common measurements used in this method are basion-bregma height, bicondylar femur length, and condylo-malleolar length of the tibia. These measurements were procured from the Plains Osteometric Databank, furnished by Dr. Richard L. Jantz. The more complex measurements are as follows. The height of the vertebral column was measured by taking the anterior height at midline for each vertebra from the second cervical vertebra (C2) to the fifth lumbar vertebra (L5) using digital sliding calipers. C2 was measured from the tip of the odontoid process to the inferior surface. The first cervical vertebra (C1) is not measured in this method because its contribution to the height of the vertebral column is incorporated into the measurement for C2. The first sacral segment (S1) was measured at midline from the superior surface of the sacrum to the superior edge of its suture with the second sacral segment (S2). In the event that presacral vertebrae were mildly damaged at midline, the measurement was taken as close to midline as possible. Severely damaged vertebrae were not measured but estimated using the estimated percent contribution of the missing vertebra to the height of the vertebral column, the same manner used to estimate missing vertebrae.

Ankle height was taken by articulating the talus and calcaneus and orienting them as they would have been in the body (Fully 1956, Lundy 1988b) and measuring the distance between the superior surface of the talus and the most inferior surface of the calcaneus using an osteometric board. This measurement is not a maximum or minimum height, but requires that the observer be able to visualize the anatomical orientation. The talus and calcaneus should be oriented approximately so that the distal half of the plantar

surface of the calcaneus is roughly parallel with the fixed end of the osteometric board to simulate the average arch of the foot. This is a difficult measurement that requires patience and practice and is probably vulnerable to significant errors.

The above measurements were summed to give a skeletal height. A correction was then added to account for the soft tissues that contribute to height, including the intervertebral discs, menisci, and joint cartilage. The value of the soft tissue correction factor depends on skeletal height. For skeletal heights less than 153.5cm, the correction is 10cm. For heights between 153.6cm and 165.4cm, 10.5cm are added. For heights over 165.5cm, 11.5cm are added (Fully 1956, Lundy 1988b).

Missing vertebrae can be estimated provided they account for no more than 20 percent of the height of the vertebral column. Fully (1956) recommends estimating vertebrae by calculating the average percent contribution of each vertebra to column height. Sciulli et al. (1990) used a simpler method, calculating the height of a missing vertebra by taking the average of the heights of the vertebrae immediately superior and inferior to the absent vertebra. This method gave results that were virtually identical to the percent contribution method.

Despite the simplicity of the Sciulli et al. (1990) method for estimating the height of missing vertebrae, the more complex percent contribution was used in this study. There were three cases where either C2 or S1 was absent and five cases where two or more consecutive vertebrae were missing, two scenarios where it was impossible to average the heights of the vertebrae immediately superior and inferior to missing vertebrae.

Percent contribution of individual vertebrae to column height was calculated for each sex using the individuals with complete vertebral columns (females N=10, males N=10). The contribution of each vertebra to column height was calculated for each individual. The individual contributions were averaged and the results were then used to estimate the heights of missing vertebrae in the remainder of the sample. See Appendix 1 for these calculations.

Supernumerary vertebrae were present in two of the males in this sample. These individuals, though complete, were not included in the percent contribution calculations. However, the presence of an extra vertebra is significant to an individual's stature (Lundy 1988a) and was included in each individual's calculations for column height and skeletal height.

A table of measurements for each individual, including estimated vertebral column heights, skeletal heights, soft tissue corrections, and final stature is available in Appendix 2.

C. Regression Methods

All samples were tested for normality before regression formulae were constructed. Kolmogorov-Smirnov tests and quantile-quantile plots were performed on the measurements for each element used in the regression formulae. See Appendix 4 for these results. Basion-bregma height, height of the vertebral column, bicondylar femur length, condylo-malleolar tibia length, articulated height of the talus and calcaneus, maximum humerus length, and maximum radius length were used in the regression formulae.

Regression formulae were calculated using the R statistics package. Two sets of regressions were performed: inverse calibrations, where the independent variable was regressed on the dependent variable (example, stature regressed onto bicondylar femur length) and classical calibrations, where the dependent variable is regressed on the independent variable and then solving the equation for the independent variable (example, femur length regressed onto stature then solving for stature) (Konigsberg et al. 1998).

Each set of calibrations has specific benefits and disadvantages. Like any stature estimation method that relies on the relationship between bone length and stature, both inverse and classical calibration formulae assume similar body proportions between the reference sample and an individual whose stature will be estimated using the regression formula. An inverse calibration also includes the assumption that an estimate that is calculated using this formula belongs to the same distribution of stature as the reference sample or a distribution that closely mirrors the reference sample. Inverse calibrations provide good population specific stature estimation formulae but may not be appropriate for use with other populations. A classic calibration does not include an assumption about an estimated case's population distribution, making it more widely applicable to other populations than inverse calibrations are. However, classic calibrations have wider confidence intervals than inverse calibrations do, resulting in less accurate estimates (Konigsberg et al. 1998).

Inverse calibrations were used in this study to produce population specific formulae for stature estimation. Classic calibration formulae were created for use with

more diverse populations. In the classical calibration formulae that utilize two bones, the lengths of the two bones were summed and that sum was regressed on stature.

Chapter IV

Results

Regression equations using inverse and classic calibration were calculated for basion-bregma height, vertebral column height, bicondylar femur length, condylo-malleolar tibia length, articulated height of the talus and calcaneus, the combination of femur and tibia lengths, maximum humerus length, maximum radius length, and the combined humerus and radius lengths. The linear regressions were plotted alongside Loess lines for comparison of the linear regressions against the best-fit Loess regressions. See Appendix 6 for these graphs.

Most elements had a significant positive correlation with stature. The sole exception is basion-bregma height in females, which had a correlation of -0.0088. The F-statistic of basion-bregma and stature for females was .001784. Regression equations were calculated for this pairing, but these equations yield ridiculous, occasionally even negative, results for stature when tested with a variety of values. They have no predictive value whatsoever and have been excluded from this study. See Appendix 3 for a complete table of correlation coefficients and figures 17 and 35, Appendix 6 for a plot of the linear and Loess regressions.

Basion-bregma height in males showed a much stronger relationship with stature than in females, with a correlation of .457. Plots of basion-bregma against stature in males show an interesting trend (see figure 26, Appendix 6). There is a steady, positive linear relationship between the two variables up to a stature value of approximately

1675mm. At this level the slope of the Loess regression line becomes negative, indicating a decrease in basion-bregma height relative to stature.

The articulated height of the talus and calcaneus is weakly correlated with stature in both sexes. The correlation in females is .343, in males it is .375. Regressions between talus-calcaneus height and stature produced somewhat small F-statistic values of 3.062 for females and 3.444 for males. The p-values for these F-statistics are both significant for $p = .05$ but not for $p = .1$, signifying that these formulae have questionable utility. In both sexes the slope of the Loess line changes from positive to negative near the mean value for talus-calcaneus height, then becomes positive again near the lower limit of the third quantile (see figures 21 and 30, Appendix 5). Although the relationships between talus-calcaneus height and stature were weak, they followed a general linear pattern and may have some minute value for stature estimation in the event that no other elements are available.

Standard errors were calculated from the variance of stature and the correlation between the bone or bones and stature as described in Konigsberg et al. (1998). It should be noted that due to the small sample size, the standard error for the classic calibration regression will approximate the true values close to the mean but will underestimate the error toward the tails of the distribution. The standard errors for the classically calibrated regressions stated here should be considered to be the minimum standard errors for these formulae.

The most accurate inverse regression estimation formula among females is the for bicondylar femur length, followed closely by the formula for combined femur and tibia lengths. The same order of accuracy is true for the classically calibrated regression

formulae. Often the combination of the femur and tibia lengths results in the most accurate formulae. However, for the females in this population the generalization does not apply.

The most accurate inverse regression formula for the males is the combination of the femur and tibia, followed by the bicondylar length of the femur. The order of accuracy is the same in the classically calibrated regressions. Unlike the situation with the regressions for females, the inclusion of the tibia in a formula with the femur improves accuracy.

Regressions developed from the humerus and radius produce good estimates of stature, especially for females. Two significant outliers were detected among the males and were excluded from the regressions. Even after the exclusion of the outliers, the humerus and radius regressions for males still produced less precise results than the regressions derived from females. In both sexes the humerus alone gave better estimates than the radius alone. The combined humerus and radius lengths produced more accurate estimates than either bone did alone.

While the upper limb bones provided reasonable estimates of stature, the lower limb bones produced more accurate estimates. This is likely because the femur and tibia directly contribute to stature while the humerus and radius do not. While the humerus and radius are strongly correlated with stature, they are more highly correlated with their corresponding lower limb bones. This suggests the lengths of the humerus and radius are closely related to lengths of femur and tibia and that their relations to stature are simply an expression of their relations to two bones that contribute substantially to stature.

Vertebral column height produced sufficiently accurate inverse and classical regression formulae. This is significant because of the tendency of the vertebrae to be among the most protected elements in a burial. While long bones are frequently subject to taphonomic processes, the vertebrae, though not necessarily well preserved, are frequently found in the same location where the body was originally interred. Missing vertebrae can be accounted for using the percent contribution to the height of the vertebral column method. Thus, if 80 percent of the vertebral column is present, a reasonable approximation of stature can still be made.

In the following equations stature is estimated in millimeters. F-statistics accompany the inverse calibration equations.

A. Inverse Regressions for Females

1) Stature regressed on Vertebral Column Height (VCH):

$$\text{Stature} = ((\text{VCH}) * 2.047) + 563.212 \pm 30.252$$

F-statistic: 27.05

2) Stature regressed on Bicondylar Femur Length (BFL):

$$\text{Stature} = ((\text{BFL}) * 2.512) + 494.105 \pm 15.939$$

F-statistic: 157.3

3) Stature regressed on Condylar-Malleolar Tibia Length (CMTL):

$$\text{Stature} = ((\text{CMTL}) * 2.243) + 741.319 \pm 22.737$$

F-statistic: 65.6

4) Stature regressed on Articulated Talus-Calcanus Height (TCH):

$$\text{Stature} = ((\text{TCH}) * 1.979) + 1410.969 \pm 41.921$$

F-statistic: 3.062

5) Stature regressed on Combined Femur and Tibia Lengths:

$$\text{Stature} = ((\text{BFL}) * 1.96) + ((\text{CMTL}) * 0.63) + 499.84 \pm 16.109$$

F-statistic: 15.55

6) Stature regressed on Humerus Length (HML):

$$\text{Stature} = ((\text{HML}) * 3.089) + 612.145 \pm 24.983$$

F-statistic: 50.38

7) Stature regressed on Radius Length (RML):

$$\text{Stature} = ((\text{RML}) * 3.09) + 813.87 \pm 24.811$$

F-statistic: 51.4

8) Stature regressed on Combined Humerus and Radius Lengths:

$$\text{Stature} = ((\text{HML}) * 1.706) + ((\text{RML}) * 1.748) + 617.335 \pm 21.403$$

F-statistic: 36.83

B. Inverse Regressions for Males

9) Stature regressed on Basion-Bregma Height (BBH):

$$\text{Stature} = ((\text{BBH}) * 6.076) + 824.661 \pm 55.041$$

F-statistic: 5.556

10) Stature regressed on Vertebral Column Height:

$$\text{Stature} = ((\text{VCH}) * 2.383) + 427.284 \pm 28.784$$

F-statistic: 76.1

11) Stature regressed on Bicondylar Femur Length:

$$\text{Stature} = ((\text{BFL}) * 3.279) + 193.512 \pm 20.317$$

F-statistic: 173.9

12) Stature regressed on Condylar-Malleolar Tibia Length:

$$\text{Stature} = ((\text{CMTL}) * 2.913) + 536.816 \pm 31.750$$

F-statistic: 58.81

13) Stature regressed on Articulated Talus-Calcaneus Height:

$$\text{Stature} = ((\text{TCH}) * 2.938) + 1437.103 \pm 57.369$$

F-statistic: 3.444

14) Stature regressed on Combined Femur and Tibia Lengths:

$$\text{Stature} = ((\text{BFL}) * 2.5372) + ((\text{CMTL}) * 0.8886)) + 183.6989 \pm 20.156$$

F-statistic: 87.87

15) Stature regressed on Humerus Length:

$$\text{Stature} = ((\text{HML}) * 4.06) + 358.72 \pm 30.189$$

F-statistic: 29.84

16) Stature regressed on Radius Length:

$$\text{Stature} = ((\text{RML}) * 3.763) + 695.899 \pm 37.478$$

F-statistic: 12.69

17) Stature regressed on Combined Humerus and Radius Lengths:

$$\text{Stature} = ((\text{HML}) * 3.225) + ((\text{RML}) * 1.779)) + 177.306 \pm 28.263$$

F-statistic: 18.66

C. Classical Regressions for Females

18) Vertebral Column Height regressed on Stature:

$$\text{Stature} = ((\text{VCH}) * 3.7879) - 263.11 \pm 41.151$$

19) Bicondylar Femur Length regressed on Stature:

$$\text{Stature} = ((\text{BFL}) * 2.8785) + 341.87 \pm 17.064$$

20) Condylar-Malleolar Tibia Length regressed on Stature:

$$\text{Stature} = ((\text{CMTL}) * 3.0294) + 463.03 \pm 26.424$$

21) Articulated Talus-Calcaneus Height regressed on Stature:

$$\text{Stature} = ((\text{TCH}) * 16.8464 + 479.43 \pm 122.300$$

22) Combined Femur and Tibia Lengths regressed on Stature:

$$\text{Stature} = ((\text{BFL} + \text{CMTL}) * 1.47601) + 400.901 \pm 17.273$$

23) Humerus Length regressed on Stature:

$$\text{Stature} = ((\text{HML}) * 4.498) + 190.87 \pm 30.151$$

24) Radius Length regressed on Stature:

$$\text{Stature} = ((\text{RML}) * 4.472) + 491.14 \pm 29.850$$

25) Combined Humerus and Radius Lengths regressed on Stature:

$$\text{Stature} = ((\text{RML} + \text{HML}) * 2.243) + 341.44 \pm 24.389$$

D. Classical Regressions for Males

26) Basion-Bregma Height regressed on Stature:

$$\text{Stature} = ((\text{BBH}) * 29.0444) - 2285.853 \pm 120.331$$

27) Vertebral Column Height regressed on Stature:

$$\text{Stature} = ((\text{VCH}) * 3.0404) + 90.5406 \pm 32.514$$

28) Bicondylar Femur Length regressed on Stature:

$$\text{Stature} = ((\text{BFL}) * 3.6751) + 17.9294 \pm 21.508$$

29) Condylar-Malleolar Tibia Length regressed on Stature:

$$\text{Stature} = ((\text{CMTL}) * 3.9526) + 140.166 \pm 36.986$$

30) Articulated Talus-Calcaneus Height regressed on Stature:

$$\text{Stature} = ((\text{TCH}) * 20.8551) + 153.843 \pm 152.839$$

31) Combined Femur and Tibia Lengths regressed on Stature:

$$\text{Stature} = ((\text{BFL} + \text{CMTL}) * 1.9044) + 76.8250 \pm 21.318$$

32) Humerus Length regressed on Stature:

$$\text{Stature} = ((\text{HML}) * 6.645) - 453.864 \pm 38.622$$

33) Radius Length regressed on Stature:

$$\text{Stature} = ((\text{RML}) * 9.398) - 710.134 \pm 59.221$$

34) Combined Humerus and Radius Lengths regressed on Stature:

$$\text{Stature} = ((\text{RML} + \text{HML}) * 3.893) - 560.003 \pm 34.813$$

Chapter V

Discussion

The properties and utility of the stature estimation formulae from the literature were tested using the mean values for femur length, tibia length, vertebral column height, male basion-bregma height, humerus length, radius length, and articulated talus-calcaneus height in several indigenous American populations and Trotter and Gleser's (1958) "Mongoloid" population. Accuracy was judged according to whether or not the estimate produced by a particular formula was within 2cm of the real value and if the estimate was within one, two, or greater than two standard error units of the actual value.

Most of the formulae tested overestimated stature in the Arikara, indicating that on average the bone used in the regression contributes more to stature in the Arikara than in the reference sample. Overestimates of stature calculated from arm and leg bones indicates that the Arikara are proportionally longer limbed than the reference sample from which the stature estimation formulae were derived. This was true of most of the regressions with the exception of the Ohio samples used in Sciulli et al. (1990) and Sciulli and Giesen (1993). The limb bone regressions from these studies overall underestimated stature in the Arikara, indicating that these reference samples have, on average, relatively longer limbs than the Arikara do.

Upon examining the statures and limb bone lengths of the populations in this study, the range of body proportions in American Indians and other indigenous American groups does not seem to follow Allen's rule for the correlation of body proportions and climate. Allen's rule states that for a geographically widespread warm-blooded species,

cold climate populations tend to have shorter arms and legs relative to their body heights than warm climate populations do (Beall and Steegmann 2000). These populations do not seem to follow that trend. The longest limbed populations in this study are found in Ohio, a temperate zone that experiences cold winters, while some of the shortest limbed are found in the similarly cool climate of Illinois and the warm climate of Mesoamerica. Perhaps Allen's rule does not apply to human populations in the Americas because of its relatively recent inhabitation with respect to human evolutionary history. See table 2 for femur stature ratios for the populations in this study.

A) Genovés – Modern Mesoamericans

Genovés's stature estimation formulae using the femur worked very well in both sexes, giving results within 2cm of the real values. The tibia formulae were less accurate with both overestimating stature in the Arikara. This suggests that the tibia contributes more to stature in the Arikara than in this sample, indicating that the Arikara have relatively longer legs than the individuals in this sample.

Table 2. Femur/Stature Ratios

	males	females
Arikara	.2691	.2699
Genovés (1967)	.2635	.2602
Sciulli et al. (1990)	.2796	.2786
Sciulli and Giesen (1993)	.2750	.2748
Trotter and Gleser "Mongoloids" (1958)	.2643	---
Trotter and Gleser Mexicans (1958)	.2687	---

B) Neumann and Waldman – Illinois Middle Mississippians

Stature estimation formulae based on femur length, tibia length, and combined femur and tibia lengths are available for this group. This population is several hundred years older than the Larson and Leavenworth Arikara, but their geographic proximity may suggest the possibility of some biological relationship to the Plains groups or of similar bioplastic responses to comparable environments. Despite their potential relatedness to Plains populations and development in similar environments, these formulae were the worst estimators among regressions derived from American Indian populations. While no standard errors are given, all formulae significantly overestimate in the Arikara, especially regarding the females. Femur and tibia length likely contributed more to the stature of the Arikara than this Middle Mississippian population.

C) Sciulli et al. - Late Archaic, Middle and, Late Woodland, and Mississippian Ohioans

Regressions were available for femur length, tibia length, combined femur and tibia lengths, and height of the vertebral column for this sample. All of the formulae worked well on the Arikara data with the exception of maximum femur length in males, indicating that the femur contributes more to stature in this sample than in the Arikara.

A corresponding though less pronounced effect is seen with the estimation of stature from the vertebral column. While the estimates for both sexes were very close to the actual values, both overestimated stature slightly. This suggests that the vertebral column contributes more to stature in the Arikara than in this sample.

D) Sciulli and Giesen – Late Archaic through Late Prehistoric Ohioans

This paper includes the formulae available in Sciulli et al. In addition, this study includes formulae for the combined femur, tibia, and talus-calcaneus, the humerus, radius, and the combined humerus-radius. Most estimates were within one standard error with only four being more than 2cm from the actual value for stature. The femur and humerus slightly underestimate stature in the Arikara.

E) Trotter and Gleser - "Mongoloids"

Regression formulae are available for the lengths of the femur, tibia, humerus, and radius. The formulae derived from this group were the only ones to give worse estimates than those from Neumann and Waldman. While the femur technically fell within one standard error, it nonetheless significantly overestimates stature. The value for the standard error for this regression is 3.80cm, which is a comparably large value for this measurement. The tibia regression overestimates stature in the Arikara by more than two standard errors. All of the bones tested are comparatively longer in the Arikara than in this sample, indicating that the Arikara have relatively longer legs than the individuals that compose this sample do.

F) Trotter and Gleser - Mexicans

The same formulae found in the "Mongoloid" sample are available for the Mexican sample. The femur, tibia, humerus, and radius overestimated stature, but did not approach the degree of inaccuracy of the "Mongoloid" population's regressions. The humerus gave the most accurate estimate, producing a result within 2cm of the actual

mean stature. It is interesting to note that this sample of a group whose ancestry includes, but likely not exclusively, an indigenous American population estimates stature better than formulae derived from the hodgepodge “Mongoloid” group which does include American Indians.

G) Konigsberg et al. – Large, Non-Population Specific Sample

The formulae from this study are derived from the Terry Collection, Trotter and Gleser’s (1952) World War II casualties, the Forensic Databank, and a small sample of African pygmies (n=19). While these regressions are not specific to an American Indian population, the reference sample is composed of 2072 modern individuals of differing ancestral backgrounds. The large sample size and variety in ancestry should minimize any bias in body proportions that often affect smaller population specific samples.

Four equations from this study were tested using Arikara data: 1) femur, inverse calibration, 2) femur, classical calibration, 2) femur and humerus, inverse calibration, and 4) femur and humerus, classical calibration. All of the equations worked well for the Arikara males, estimating the mean stature to within two centimeters of the mean Fully stature. The classical calibration formulae performed well for the Arikara females, but the inverse calibration formulae did not, producing estimates between one and two values of the square root of the integrated root mean square error. All of the formulae overestimated stature for females, especially the inverse calibrations. This may be due to the bias introduced to the sample by the all-male World War II casualties (n=1042), especially regarding its influence on the distribution of stature in the reference sample. See Appendix 4, table 14.

H) Secular Change in the Arikara

The Larson and Leavenworth sites represent two phases in the recent history of the Arikara. Stature estimates for the individuals from these two sites can provide information about possible secular trends in stature for this group. A third source of data for Arikara statures is Boas's 1895 monograph (Bass et al. 1971) which includes stature measurements for 46 males and a lesser but unspecified number of females.

Additionally, Bass et al. includes several estimates of stature for the Leavenworth site calculated from formulae derived from American Indian and East Asian populations.

Overall, there seems to be trend toward increasing stature during the approximately 200 years between the settlement of the Larson site and Boas's measure of living stature. I would disregard the female average calculated from the estimates given in Bass et al. (1971). One estimate for the females was calculated from Trotter and Gleser's (1952) equation for white females and produces a result greater than the estimates calculated from American Indian derived formulae. Disregarding the outlier estimate gives an average stature of 157.8cm for the Leavenworth females which falls close to the mean statures for the Boas data (see table 3, this page).

The change in stature is expressed differently in the Arikara males and females. The males show a net gain of 5.5cm, or 3.25 percent of the mean stature from the Boas data, while the females show a gain of 3.4cm from the Larson site to the time of Boas's measurements, which comprises 2.17 percent of the mean stature from the Boas data. Also, the maximum female stature may not be from the latest time period as it is in the males. If the stature estimates from Bass et al. (1971), excluding the estimate made from

the Trotter and Gleser (1952) formulae, are correct, then the maximum stature in females occurred during the habitation of the Leavenworth site and not during the late 19th century as represented by the Boas data.

Table 3. Comparison of Arikara Statures for the Larson and Leavenworth sites and the Boas Data (in centimeters)

	Males	Females
Larson (Fully Estimates)	163.5	153.4
Leavenworth (Fully Estimates)	167.7	153.8
Leavenworth (averages from Bass et al.)	168.3	159.4
Boas Data	169	156.8

Chapter VI

Conclusion

For the Arikara, the most accurate estimator of stature for females is the bicondylar length of the femur. For males, the best estimator is the combined lengths of the femur and tibia. All formulae involving the femur and tibia are accurate enough for estimating stature in populations with similar proportions between the elements tested and stature.

Among Arikara females, basion-bregma height cannot be used to predict stature. Basion-bregma height has some stature predicting capabilities among Arikara males, but the relationship between the two quantities does not approximate linearity. The classically calibrated regression for basion-bregma height in males produced standard errors that are much too large to make this formula of much use.

The classical and inverse regressions of the height of the vertebral column produced surprisingly accurate formulae in both sexes. In the event that enough vertebrae to account for 80 percent of the vertebral column height are present, a reasonably approximation of stature can be made.

The humerus and radius produced useful formulae, especially for females. The bones of the leg give better estimates than those of the arm, probably because the femur and tibia directly contribute to stature but the radius and humerus, while still strongly correlated with stature, do not. The humerus and radius are more strongly correlated with the corresponding leg bones, indicating that their correlations with stature are the expressions of their stronger correlations with the femur and tibia.

The patterning of male basion-bregma height and talus-calcaneus height in both sexes presents an interesting puzzle. The relationships are not linear with stature; in fact, they appear to hit a maximum value of their contributions to the stature. This may be that an increased cranial vault height or talus-calcaneus height is biomechanically impractical or otherwise disadvantageous after a certain proportion to stature has been achieved. This subject has not been extensively examined or explored in this study.

Sciulli et al. and Sciulli and Giesen's regression formulae predicted stature in the Arikara very well. While this may be due to geographic proximity, regression formulae derived from an Illinois Middle Mississippian group performed very poorly for the Arikara, rivaling the inaccuracy of Trotter and Gleser's "Mongoloid" sample. Perhaps this is not an expression of the dissimilarity in proportions between the Illinois Middle Mississippians but of the fact that Neumann and Waldman's (1967) method of using grave lengths to estimate stature does not provide accurate estimates.

The stature prediction formulae derived from the Arikara data were tested using the mean values for bone lengths and stature from the American Indian stature estimation literature. In most cases the classically calibrated formulae performed better than the inverse calibration formulae, as is expected. The sole exception was the Mesoamerican sample from Genovés (1967), which illustrates several interesting points. The mean statures of the population were very close to those for the Arikara. However, the two groups differed in the degree of how much the femur and tibia contributed to stature. Because the mean statures between these groups were very close and the contributions of the femur and tibia lengths to stature were not, the inverse regressions worked best for this population. This comes with the warning that simply because the average statures

between two groups are similar, the proportionality of long bones to stature may not be. In stature estimation, similar bone-to-stature proportions are more significant than similar distributions of stature.

The cross-population applicability of classically calibrated regressions developed from a sample this small and narrow is questionable. Further data could be gathered on the estimated living statures, long bone lengths, and vertebral column and cranial vault heights of a variety of Native North Americans groups and incorporated with this data to create regression formulae of greater utility.

Further research could also be conducted on the accuracy of the Fully method. There are several potential problems with this method. It was developed from a sample of white males, so its pertinence to other populations and females is in question. Occasions for testing its precision are limited, but donated skeletal collections that include reliable records of living stature could provide a setting in which this research could be realized.

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Appendices

Appendix 1 – Calculations for Estimating Vertebrae

The heights of missing vertebrae were calculated using the average percent contribution of each vertebra to column height. Example totals are given.

1. Sum the heights of the vertebrae present.

Ex: 411 cm

2. Sum the average percent contributions of the missing vertebra(e) and convert the percent contributions of the missing vertebrae to a decimal value.

Ex. $12.07829\% / 100 = .1207829$

3. Subtract the decimal value of the missing vertebrae (3) from one to give the decimal value of the present vertebrae.

Ex. $1 - .1207829 = .8792171$

4. Set column subtotal (1) equal to the average contribution of present vertebrae (3) times x :

Ex. $411 \text{ cm} = .8792171x$

5. Solve for x to get the estimated height of the vertebral column:

Ex. $x = 467.46$

Appendix 2 – Measurements

Table 4. Measurements and stature estimates for females. 39WW2 is the Larson site's designation; 39CO9 is the Leavenworth site. "f" designates the feature from which the burial was excavated; the last portion of the information under the "Burial" heading is the number assigned to the burial.

Burial	bas-breg	vert.col.	femur	tibia	talus-cal.	skeletal ht.	soft tiss.	stature	humerus	radius
39ww2 f101 b12b	124	485.14	399	344	74.5	1426.64	100	1526.6	289	226
39ww2 f201 9a	126	483.18	426	355	70	1460.18	100	1560.2	309	243
39ww2 f201 34b	131	464.67	439	388	71.5	1494.17	100	1594.2	308	258
39ww2 f201 55f	129	448.33	395	348	68	1388.33	100	1488.3	290	228
39ww2 f201 64a	133	461.74	421	366	52.5	1434.24	100	1534.2	305	237
39ww2 f201 111c	132	457.92	394	323	72.5	1379.42	100	1479.4	283	207
39ww2 f201 113d	131	491.91	435	380	64	1501.91	100	1601.9	310	238
39ww2 f201 114b	128	471.3	393	328	52	1372.3	100	1472.3	285	213
39ww2 f201 120b	119	463.3	409	361	55	1407.3	100	1507.3		
39ww2 f201 124f	132	454.09	386	331	53.5	1356.59	100	1456.6	285	216
39ww2 f201 b129b	127	490.38	422	358	61.5	1458.88	100	1558.9	301	241
39ww2 f201 132	136	471.79	420	359	54	1440.79	100	1540.8	297	240
39ww2 f201 135	131	464.51	399	335	55.5	1385.01	100	1485	288	227
39ww2 f201 137c	125	497.52	437	375	62	1496.52	100	1596.5	310	245
39ww2 f201 142	132	508.26	437	357	63.5	1497.76	100	1597.8	306	237
39ww2 f301 29b	132	467.46	416	349	60.5	1424.96	100	1525	305	236
39ww2 f301 41a	132	488.85	428	382	58	1488.85	100	1588.9	312	251
39ww2 f301 49a	128	457.56	407	353	52.5	1398.06	100	1498.1	280	227
39ww2 f301 50b	129	476.97	390	332	56	1383.97	100	1484	290	223
39ww2 f301 54e	131	496.59	400	353	67	1447.59	100	1547.6	296	242
39ww2 f301 60b	132	491.81	430	364	61	1478.81	100	1578.8	309	233
39co9 f101 31a	130	475.95	424	347	72.5	1449.45	100	1549.5		
39co9 f102 41a	123	477.9	432	369	76.5	1478.4	100	1578.4	332	248
39co9 f201 6	136	453.42	408	343	70.5	1410.92	100	1510.9	291	232
39co9 f202 17c	126	465.76	414	346	62	1413.76	100	1513.8	291	220
average	129.4	474.65	414	354	62.66	1434.992	100	1535	299	233

Table 5. Measurements and stature estimates for males, following the same naming conventions as above.

Burial	bas-breg	vert.col.	femur	tibia	talus-cal.	skeletal ht.	soft tiss.	stature	humerus	radius
39ww2 f201 b6a	133	510.55	431	363	82	1519.55	100	1619.55	307	233
39ww2 f201 32b	139	496.93	442	378	81.5	1537.43	105	1642.43	313	249
39ww2 f201 32c	139	520.19	443	398	76.5	1576.69	105	1681.69	312	259
39ww2 f201 66	137	513.93	459	387	67	1563.93	105	1668.93	319	254
39ww2 f201 75a	140	525.9	451	394	64.5	1575.4	105	1680.4	321	259
39ww2 f201 86	137	525.65	445	393	71	1571.65	105	1676.65	321	254
39ww2 f201 97g	126	504.14	434	370	60	1493.64	100	1593.64	310	250
39ww2 f201 124b	141	488.93	434	384	74.5	1522.43	100	1622.43	298	245
39ww2 f201 124g	135	480.35	420	365	57.5	1457.85	100	1557.85	300	246
39ww2 f201 127b	136	524.38	460	382	69	1571.38	105	1676.38	328	263
39ww2 f201 145d	141	500.52	437	362	76.5	1517.02	100	1617.02	320	234
39ww2 f201 148g	136	528.05	449	394	68	1575.05	105	1680.05	322	258
39ww2 f301 b2f	140	539.2	431	366	64.5	1540.7	105	1645.7	318	252
39ww2 f301 3h	138	510.25	438	377	66.5	1529.75	100	1629.75	311	251
39ww2 f301 42	138	502.02	428	360	67	1495.02	100	1595.02	301	245
39ww2 f301 62b	131	469.71	429	382	57	1468.71	100	1568.71	311	254
39co9 f101 3b	125	474.01	414	372	76	1461.01	100	1561.01	303	241
39co9 f102 12a	133	547.16	454	384	78.5	1596.66	105	1701.66	329	256
39co9 f102 17	139	538.86	488	415	85.5	1666.36	115	1781.36	361	270
39co9 f102 22	130	515.71	446	371	80	1542.71	105	1647.71	323	248
39co9 f102 46	136	548.15	480	423	73	1660.15	115	1775.15		
39co9 f102 55	137	533.14	459	403	73.5	1605.64	105	1710.64	326	252
39co9 f202 3	128	480.14	427	347	78	1460.14	100	1560.14	309	238
average	135.435	512.08	443	381	71.63	1543.864	103.7	1647.56	317	251

Appendix 3 – Means, Variances, Covariances, and Correlations

Table 6. Mean Values for Females with Percent Contribution of Elements to Stature

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
means	129.4	474.652	414.44	353.84	62.66	298.8	233.36	1534.992
% contribution	8.43001	30.9221	26.9995	23.0516	4.08211	19.4659	15.2027	-----

Table 7. Correlations for females

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
basion-bregma		-0.11682	-0.00654	-0.07772	-0.13866	-0.15004	-0.00574	-0.00881
vertebral col.	-0.11682		0.54519	0.41486	0.14214	0.51906	0.44729	0.73515
femur	-0.00654	0.54519		0.84898	0.23837	0.82461	0.78627	0.93405
tibia	-0.07772	0.41486	0.84898		0.11028	0.76344	0.87873	0.86047
talus-cal.	-0.13866	0.14214	0.23837	0.11028		0.32393	0.24012	0.34278
humerus	-0.15004	0.51906	0.82461	0.76344	0.32393		0.78889	0.8286
radius	-0.00574	0.44729	0.78627	0.87873	0.24012	0.78889		0.83119
stature	-0.00881	0.73515	0.93405	0.86047	0.34278	0.8286	0.83119	

Table 8. Variance/Covariance Matrix for females

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
basion-breg.	15.9167	-7.46808	-0.43333	-5.3083	-4.275	-7.1667	-0.275	-1.56808
vertebral col.	-7.46808	256.754	144.979	113.799	17.60106	99.5743	86.0283	525.665
femur	-0.43333	144.979	275.423	241.198	30.5725	163.842	156.627	691.74
tibia	-5.30833	113.799	241.198	293.057	14.5892	156.467	180.56	657.335
talus-calc.	-4.275	17.6011	30.5725	14.5892	59.7233	29.9708	22.2733	118.211
humerus	-7.16667	99.5743	163.842	156.467	29.9708	143.333	113.367	442.687
radius	-0.275	86.0283	156.627	180.56	22.2733	113.367	144.073	445.213
stature	-1.56808	525.665	691.74	657.335	118.211	442.687	445.213	1991.38

Table 9. Mean Values for Males with Percent Contribution of Elements to Stature

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
means	135.435	512.081	443.413	381.304	71.63043	316.522	250.522	1647.56
% contribution	8.22033	31.0812	26.9133	23.1436	4.347667	19.2116	15.2056	-----

Table 10. Correlations for males

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
basion-bregma		0.39751	0.36132	0.34602	0.05822	0.2244	0.28189	0.45741
vertebral col.	0.39751		0.76557	0.61617	0.23258	0.66324	0.55644	0.88528
femur	0.36132	0.76557		0.81624	0.32548	0.80923	0.66764	0.94459
tibia	0.34602	0.61617	0.81624		0.13239	0.55669	0.69973	0.85841
talus-calc.	0.05822	0.23258	0.32548	0.13239		0.37554	-0.12343	0.37536
humerus	0.2244	0.66324	0.80923	0.55669	0.37554		0.67286	0.78167
radius	0.28189	0.55644	0.66764	0.69973	-0.12343	0.67286		0.63285
stature	0.45741	0.88528	0.94459	0.85841	0.37536	0.78167	0.63285	

Table 11. Variance/Covariance Matrix for males

	bas-breg	vert. col.	femur	tibia	talus-cal.	humerus	radius	stature
basion-bregma	21.7115	42.5903	30.0168	29.4071	2.14526	13.7629	11.6265	131.918
vertebral col.	42.5903	528.736	313.86	258.422	42.2885	200.742	113.256	1259.96
femur	30.0168	313.86	317.878	265.437	45.8869	189.911	105.366	1042.39
tibia	29.4071	258.422	265.437	332.676	19.0949	133.652	112.97	969.088
talus-calc.	2.14526	42.2885	45.8869	19.0949	62.5277	39.0879	-8.63933	183.712
humerus	13.7629	200.742	189.911	133.652	39.0879	86.8476	78.3972	352.604
radius	11.6265	113.256	105.366	112.97	-8.63933	78.3972	66.2571	249.346
stature	131.918	1259.96	1042.39	969.088	183.712	352.604	249.346	3831

Appendix 4 – Estimating Arikara Stature Using Formulae Derived from Other Groups

Table 12. Mean stature estimates for the Arikara males. Estimates are calculated from formulae derived from other American Indian or indigenous American groups. Estimates are classified as less than one, between one and two, and over two standard deviation from the mean stature calculated by the Fully method. An asterisk denotes estimates that were within 2cm of the mean value for stature. Bold type indicates an underestimate of stature. Note: Neumann and Waldman (1967) give no standard deviation with their formulae. Absolute difference between the estimate and the mean value for stature (in millimeters) is expressed instead.

	humerus	radius	hum+rad	vert.col.	femur	tibia	fem+tib	fem+tib+tal-cal
Genoves (1967)	---	---	---	---	<1*	<1	---	---
Neumann and Waldman (1967)	---	---	---	---	32.54	37.54	35.24	---
Sciulli et al. (1990)	---	---	---	<1	<1	<1*	<1*	---
Sciulli and Giesen (1993)	>2	>2	>2	---	<1	<1*	<1*	<1*
Trotter and Gleser "Mongoloid" (1958)	<1	1>x>2	1>x>2	---	<1	>2	1>x>2	---
Trotter and Gleser Mexican (1958)	<1*	1>x>2	---	---	<1	1>x>2	---	---

Table 13. Mean stature estimates for the Arikara females. Follows the same conventions as table 10.

	humerus	radius	vert.col.	bas-breg+v.c.	femur	tibia	fem+tib	fem+tib+talus-cal.
Genoves (1967)	---	---	---	---	<1*	1>x>2	---	---
Neumann and Waldman (1967)	---	---	---	---	54.51	55.91	55.61	---
Sciulli et al. (1990)	---	---	<1	---	1>x>2	<1	<1*	---
Sciulli and Giesen (1993)	>2	>2	---	>2	<1*	<1	<1*	<1*

Table 14. Mean stature estimates for Arikara males and females using Konigsberg et al. (1998). Follows the same conventions as table 10.

	femur inverse	femur classical	fem+hum inverse	fem+hum classical
females	1>x>2	<1*	1>x>2	<1*
males	<1*	<1*	<1*	<1*

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Appendix 5 – Kolmogorov-Smirnov Tests and Quantile-Quantile Plots for Each Element

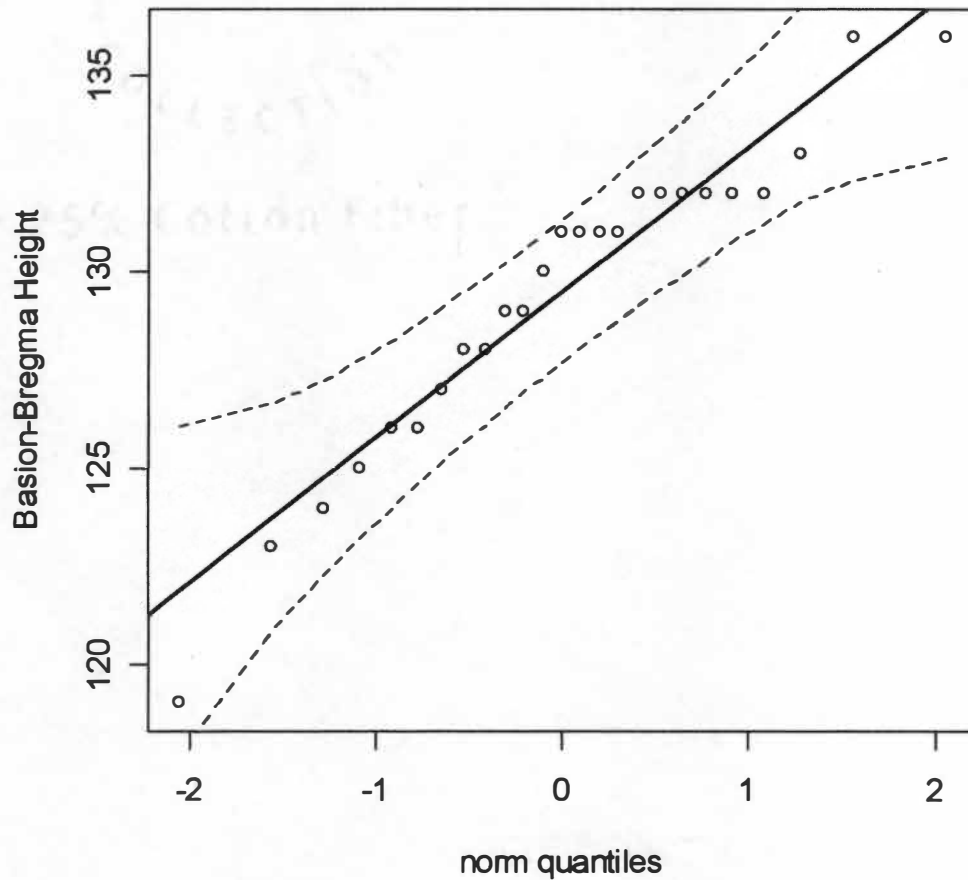


Figure 1. Females, Basion-Bregma Height. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.4223

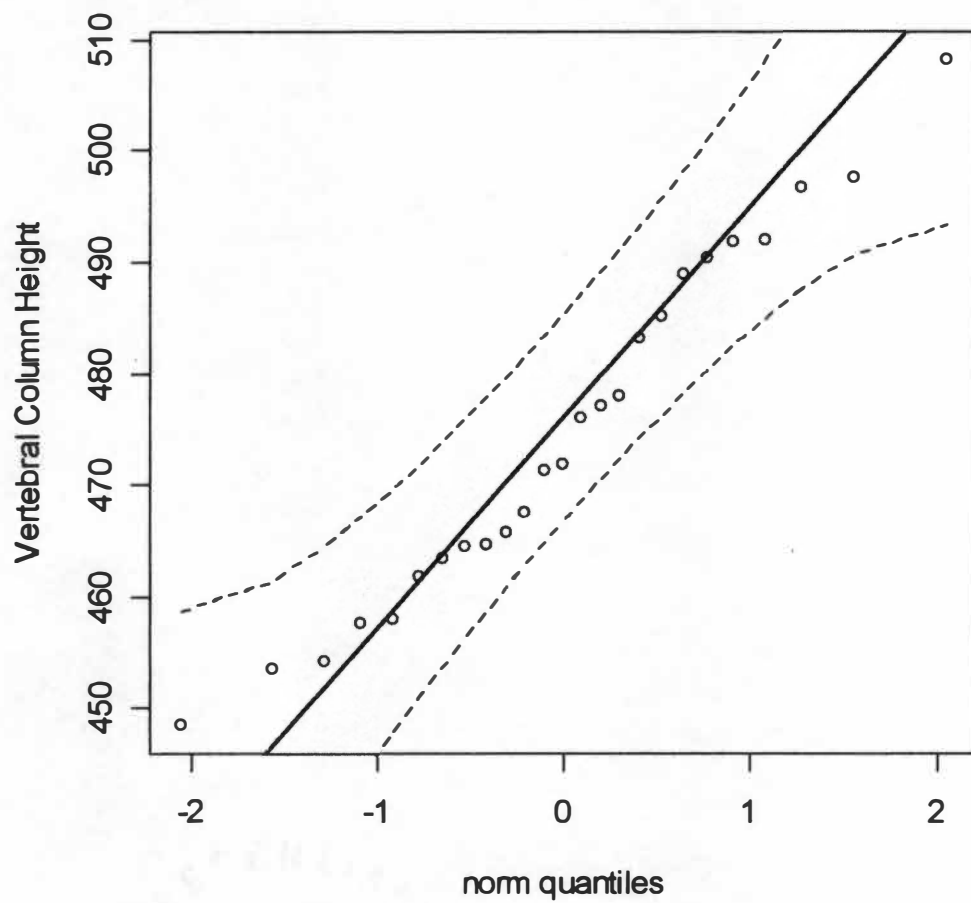


Figure 2. Females, Vertebral Column Height. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.9057

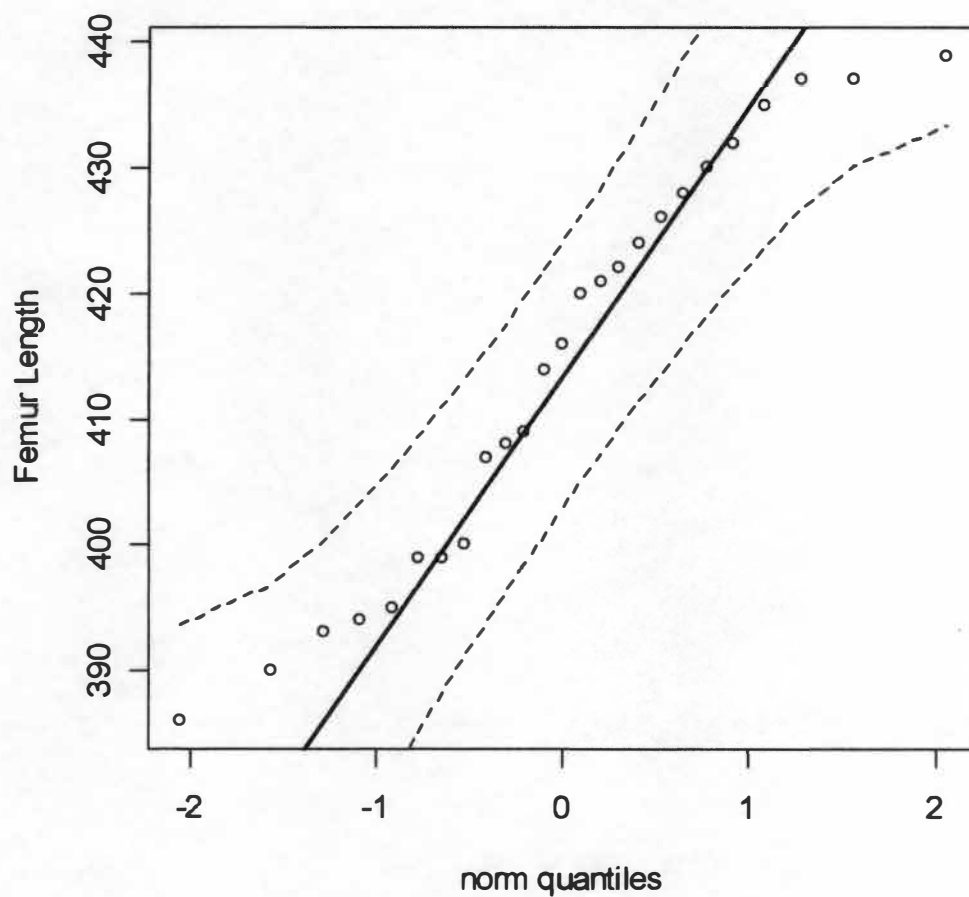


Figure 3. Females, Bicondylar Femur Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.8083

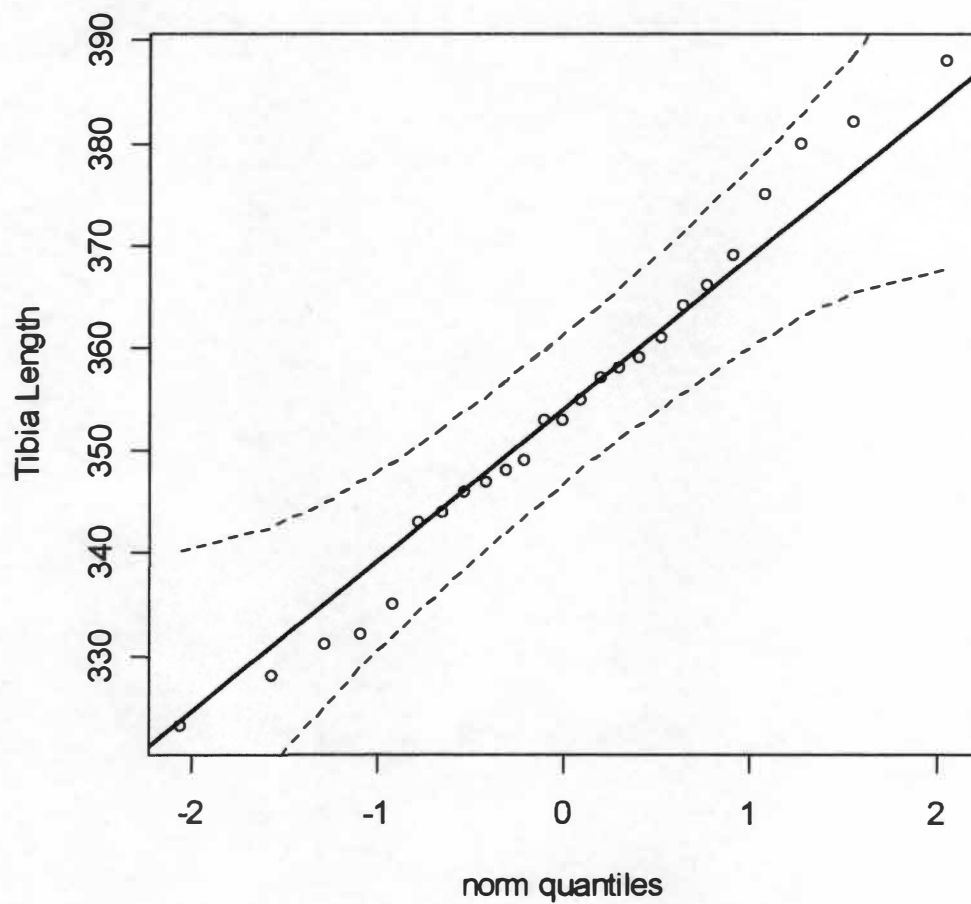


Figure 4. Females, Condylar-Malleolar Tibia Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 1

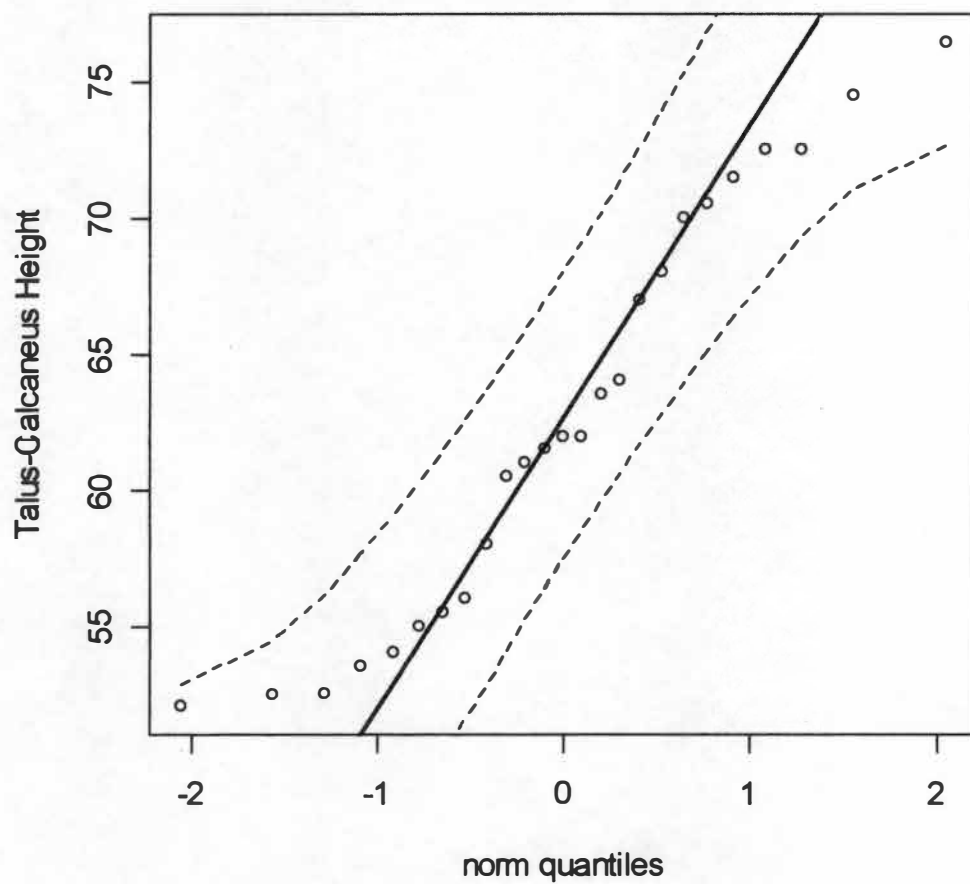


Figure 5. Females, Articulated Height of the Talus and Calcaneus. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.8252

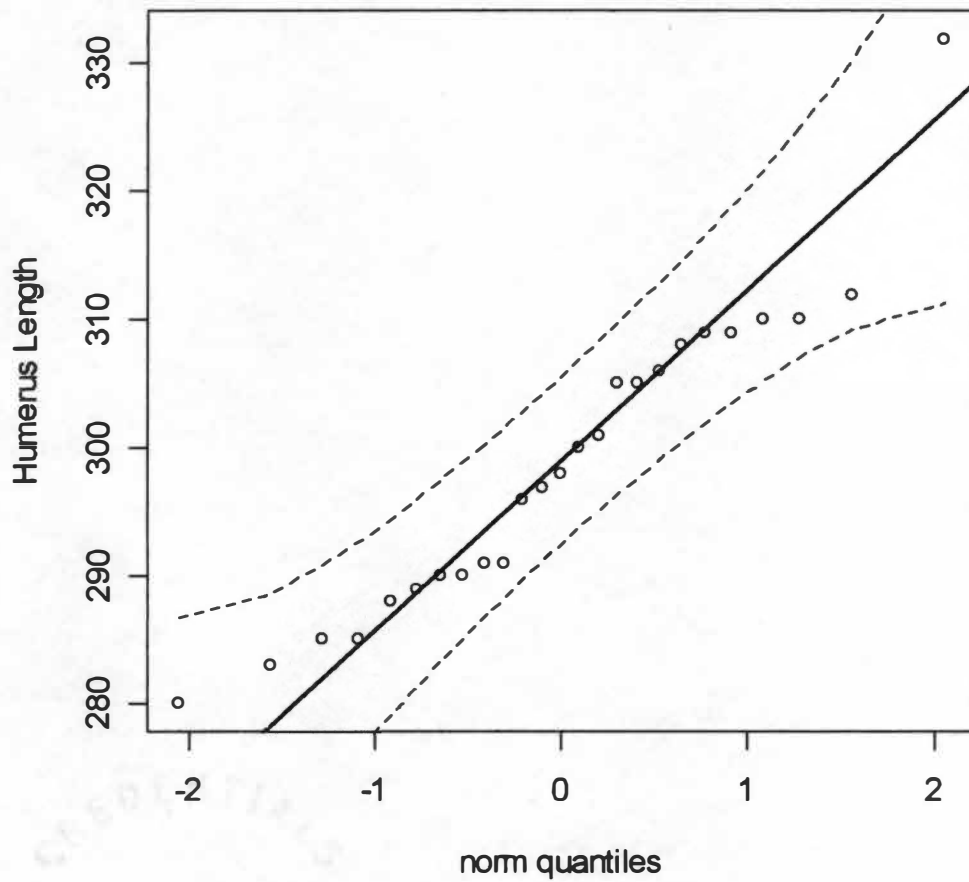


Figure 6. Females, Maximum Humerus Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.6892

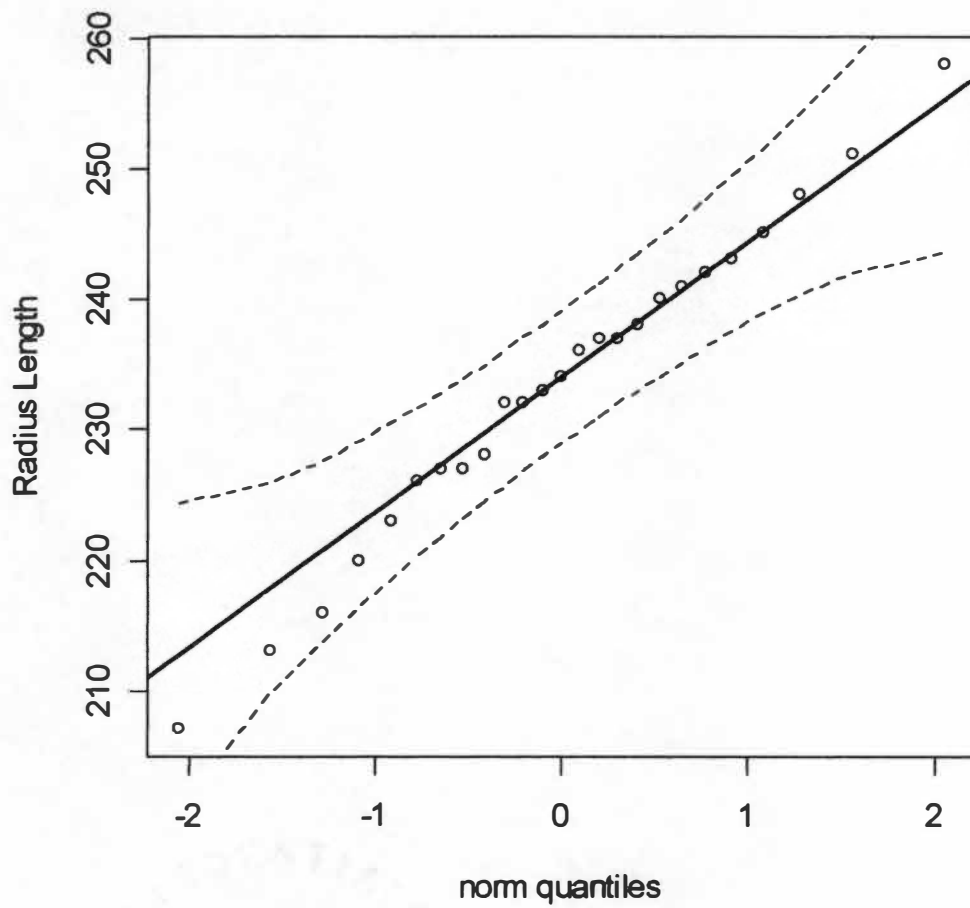


Figure 7. Females, Maximum Radius Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.978

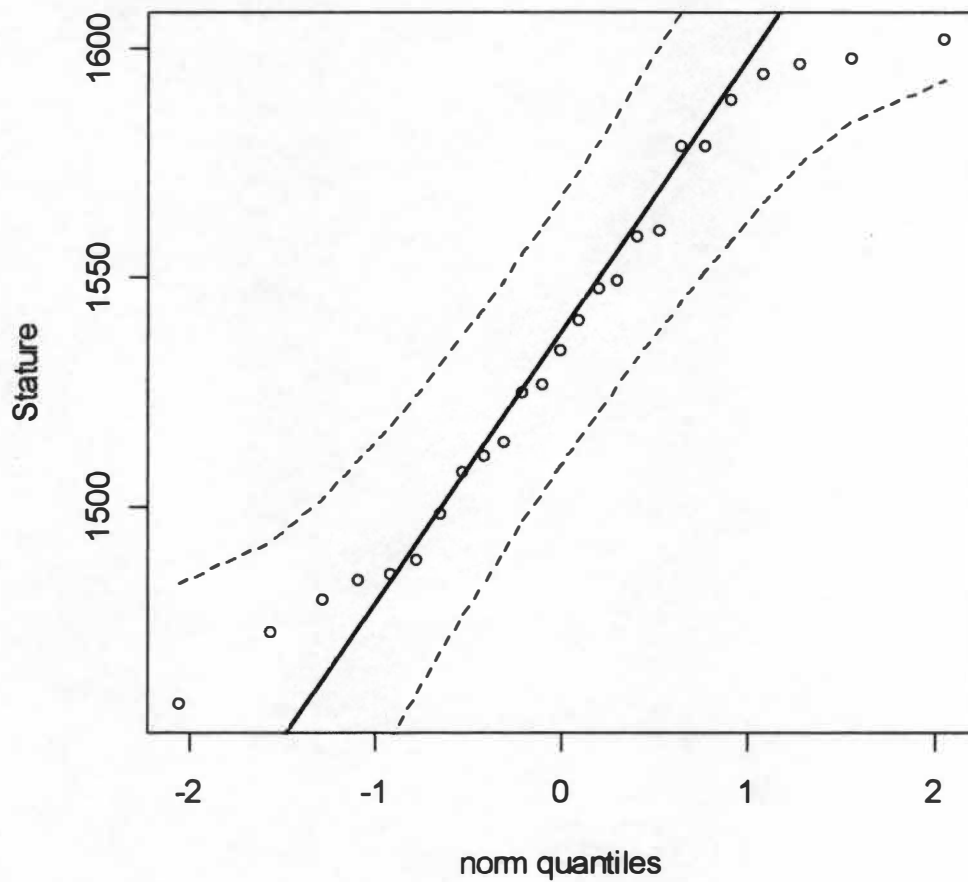


Figure 8. Females, Stature. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.8976

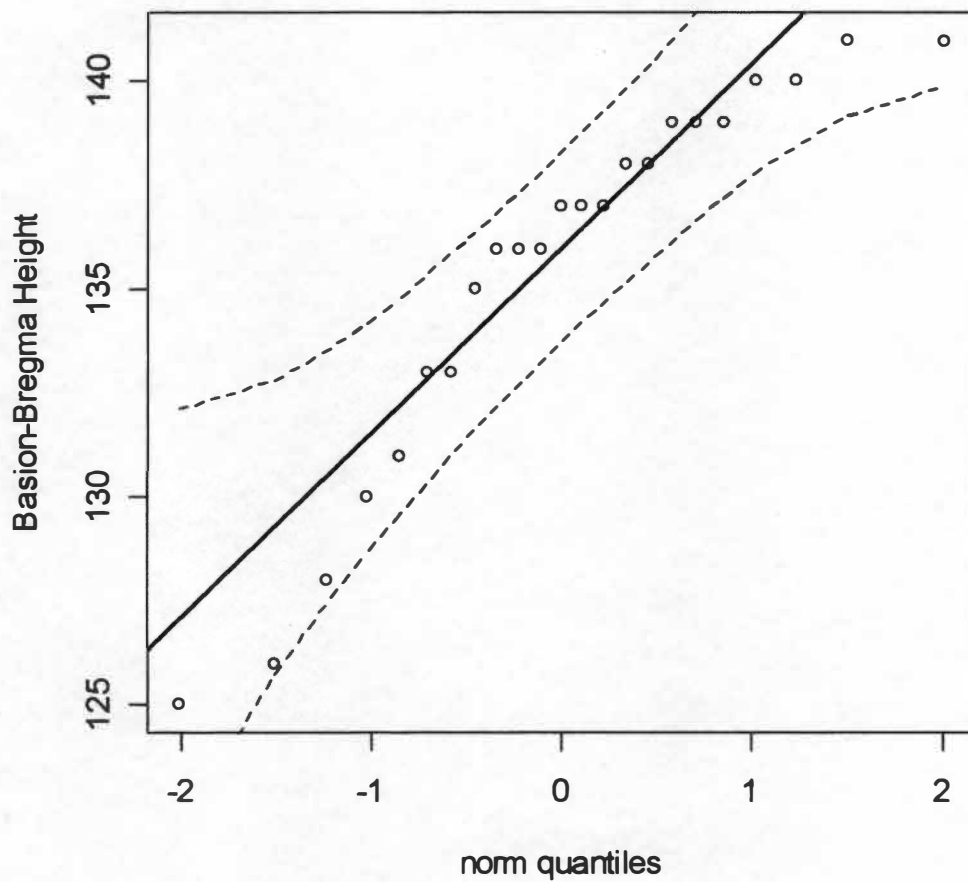


Figure 9. Males, Basion-Bregma Height. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.3138

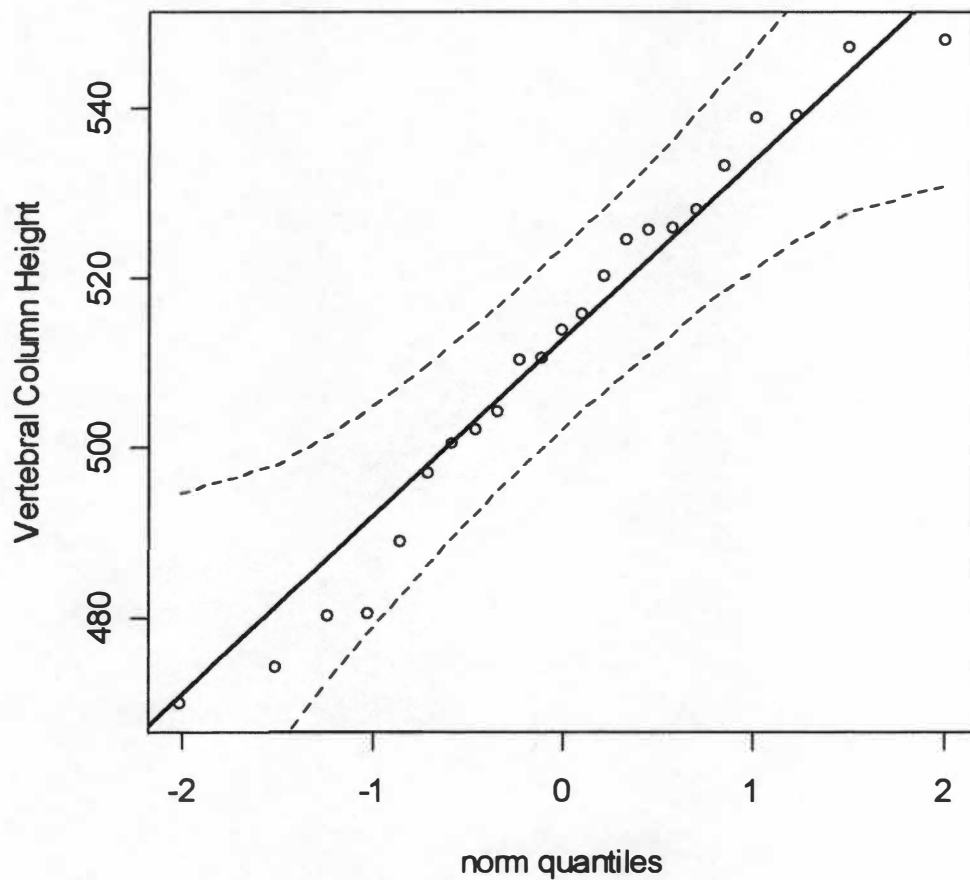


Figure 10. Males, Vertebral Column Height. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.9857

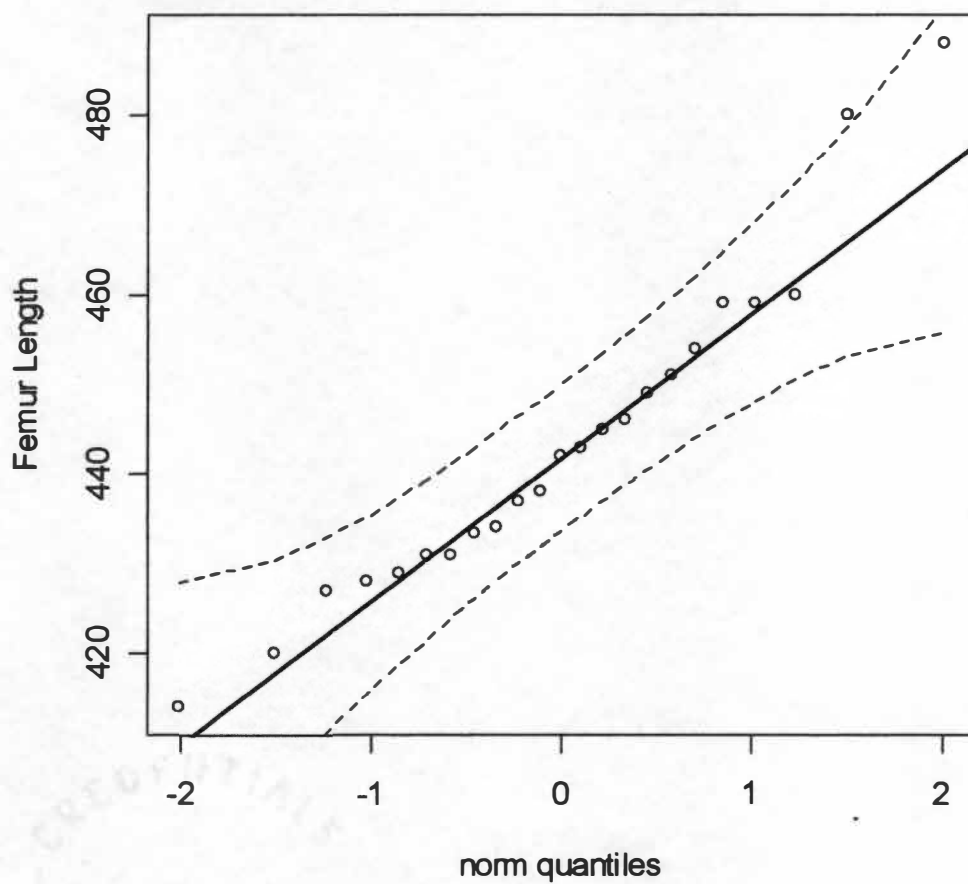


Figure 11. Males, Bicondylar Femur Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.981

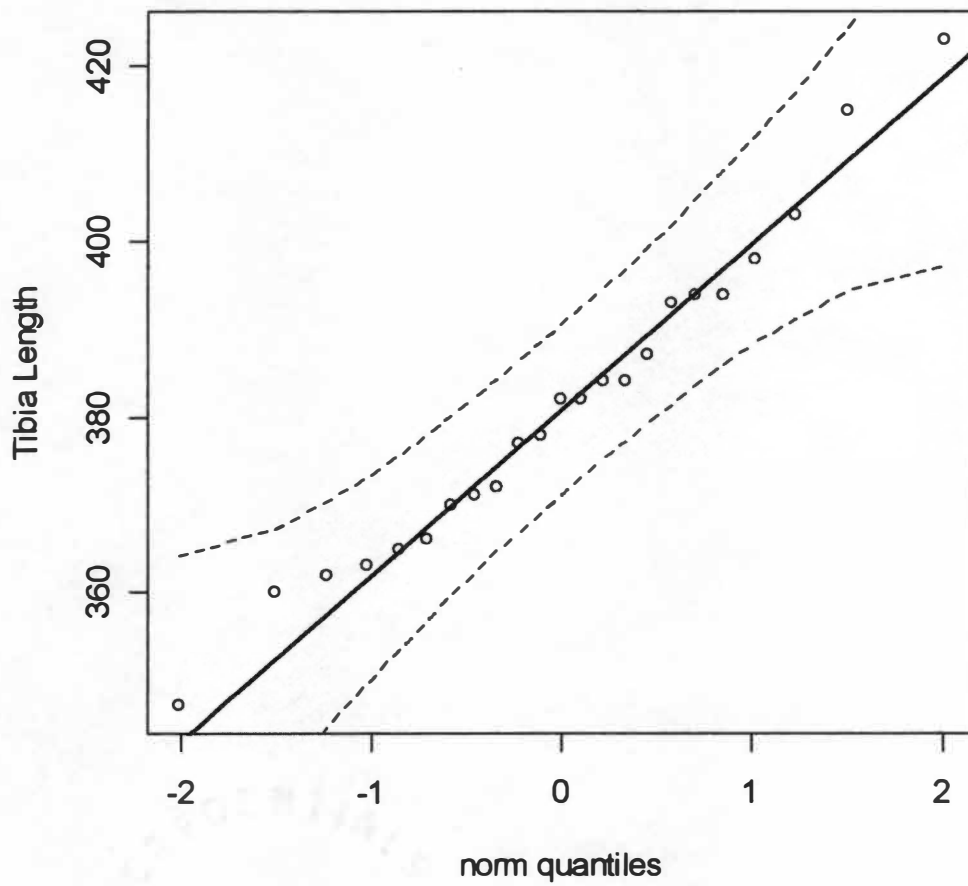


Figure 12. Males, Condylar-Malleolar Tibia Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.988

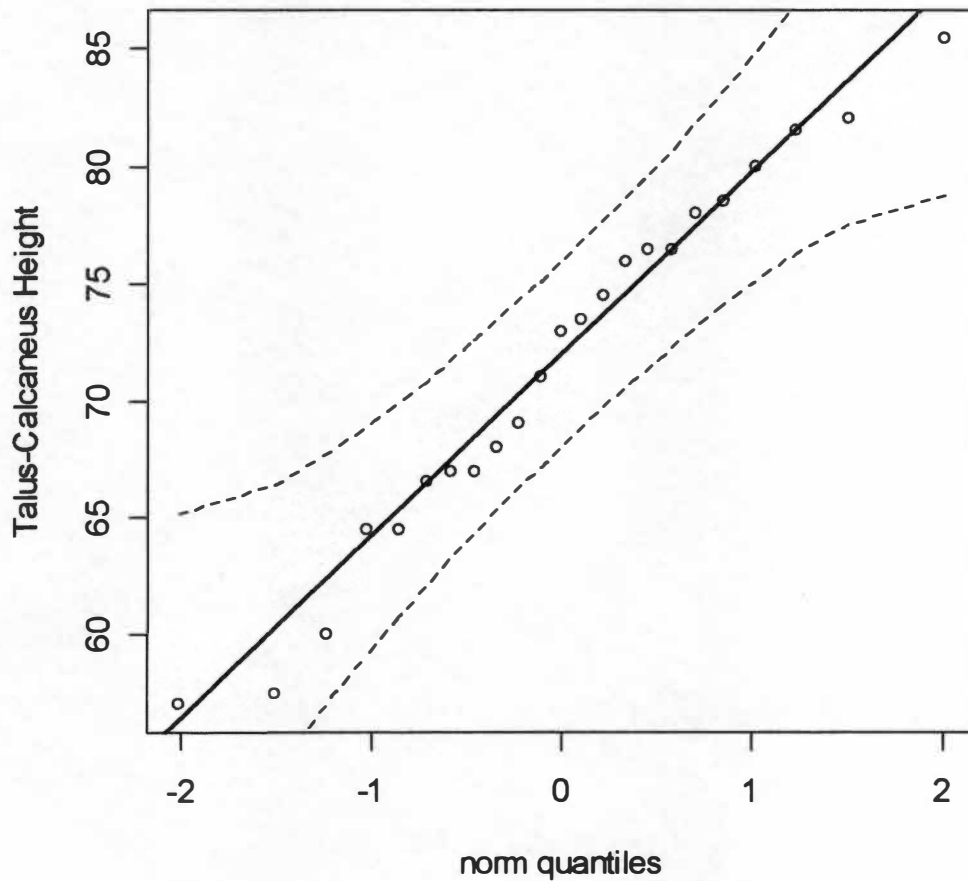


Figure 13. Males, Articulated Height of the Talus and Calcaneus. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.973

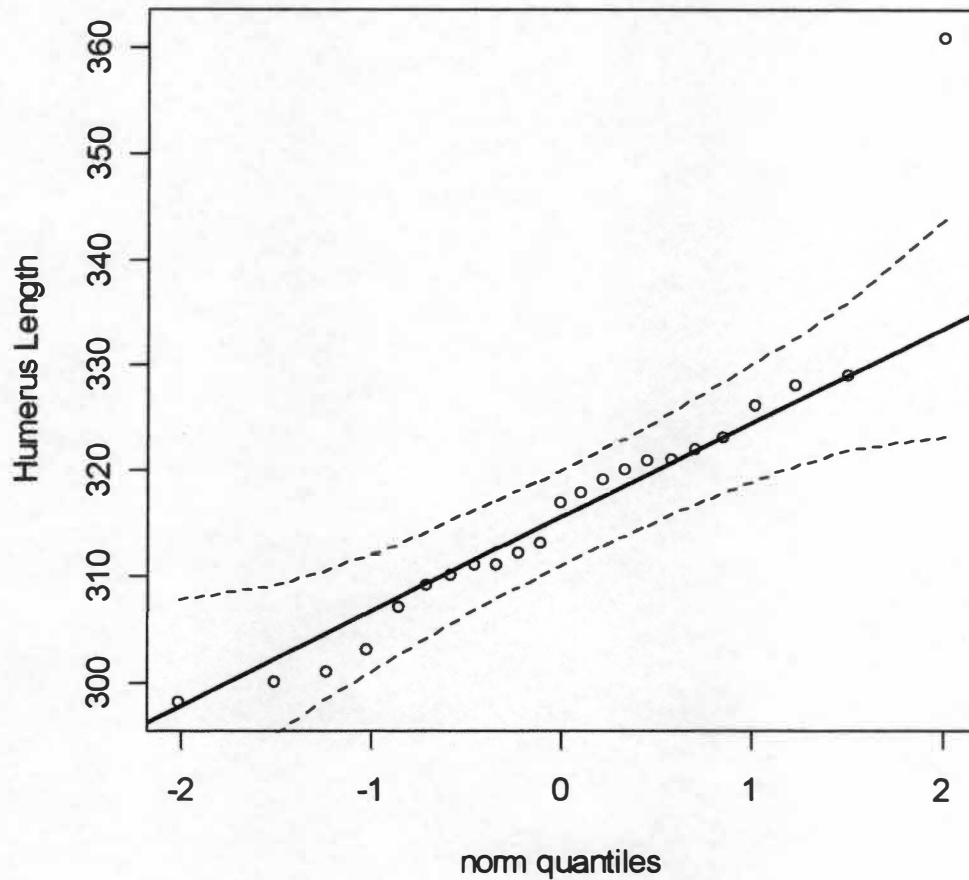


Figure 14. Males, Maximum Humerus Length. Quantile-Quantile plot and K-S test. Outlier was excluded from regressions.

Kolmogorov-Smirnov Test:

p-value = 0.7781

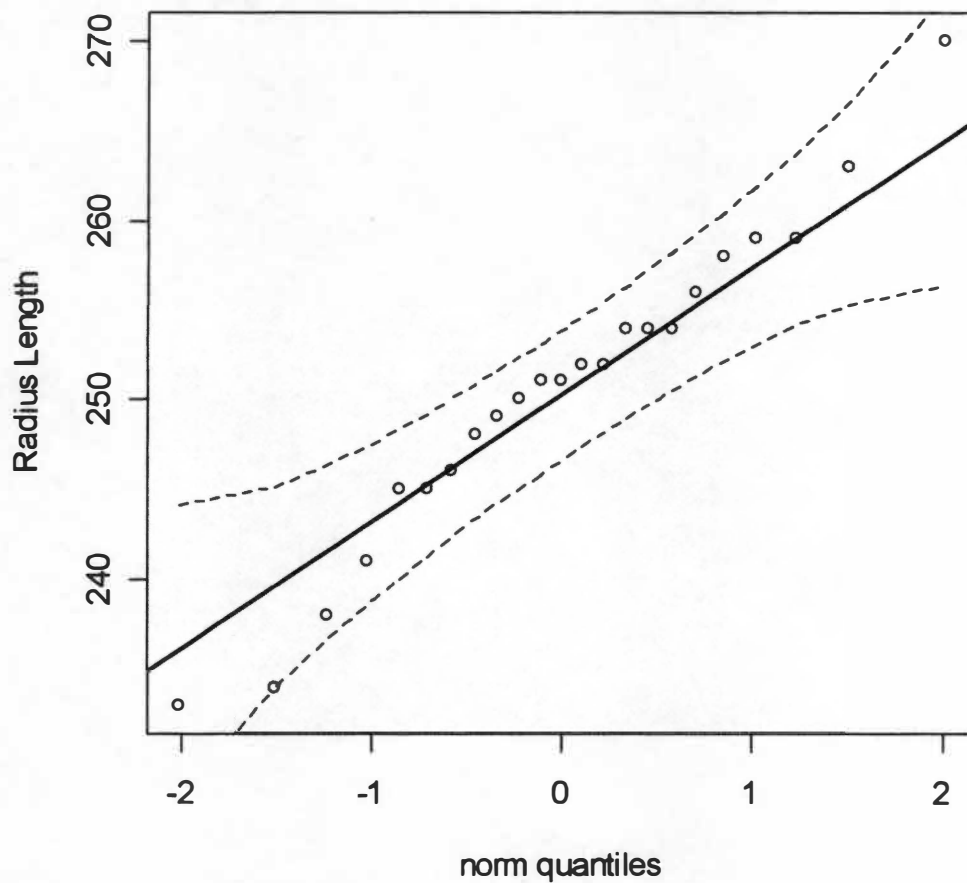


Figure 15. Males, Maximum Radius Length. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.9893

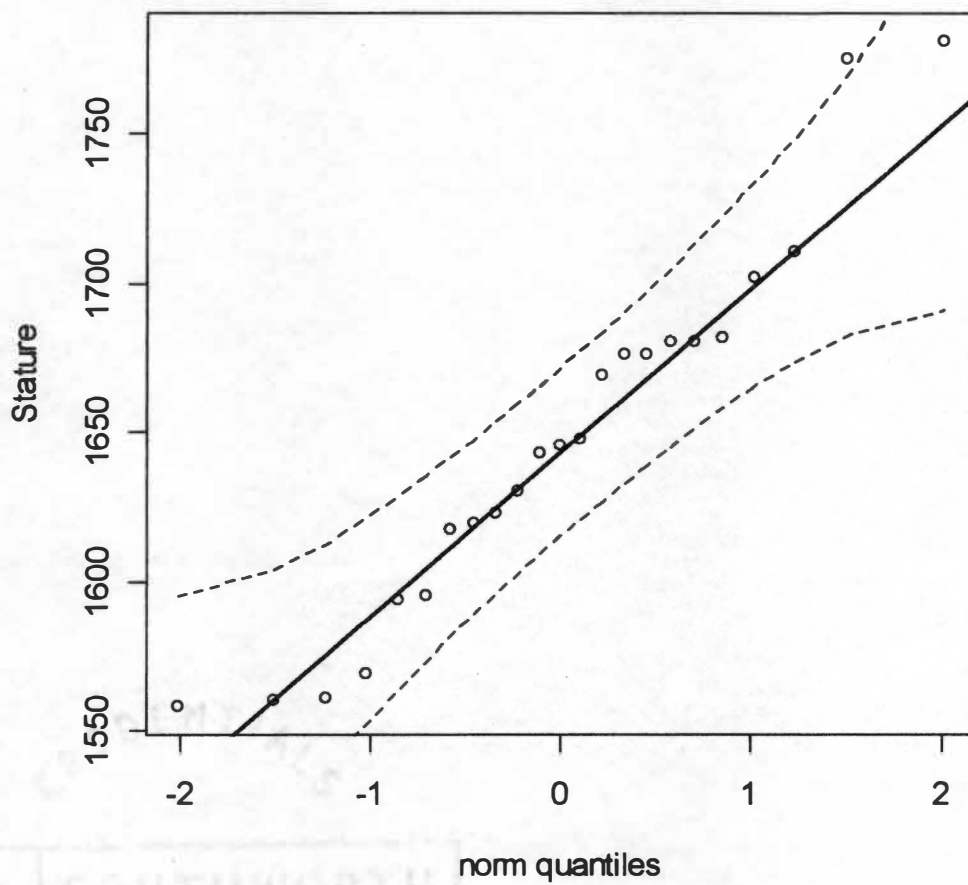


Figure 16. Males, Stature. Quantile-Quantile plot and K-S test.

Kolmogorov-Smirnov Test:

p-value = 0.9125

Appendix 6 – Linear and Loess Regression Plots

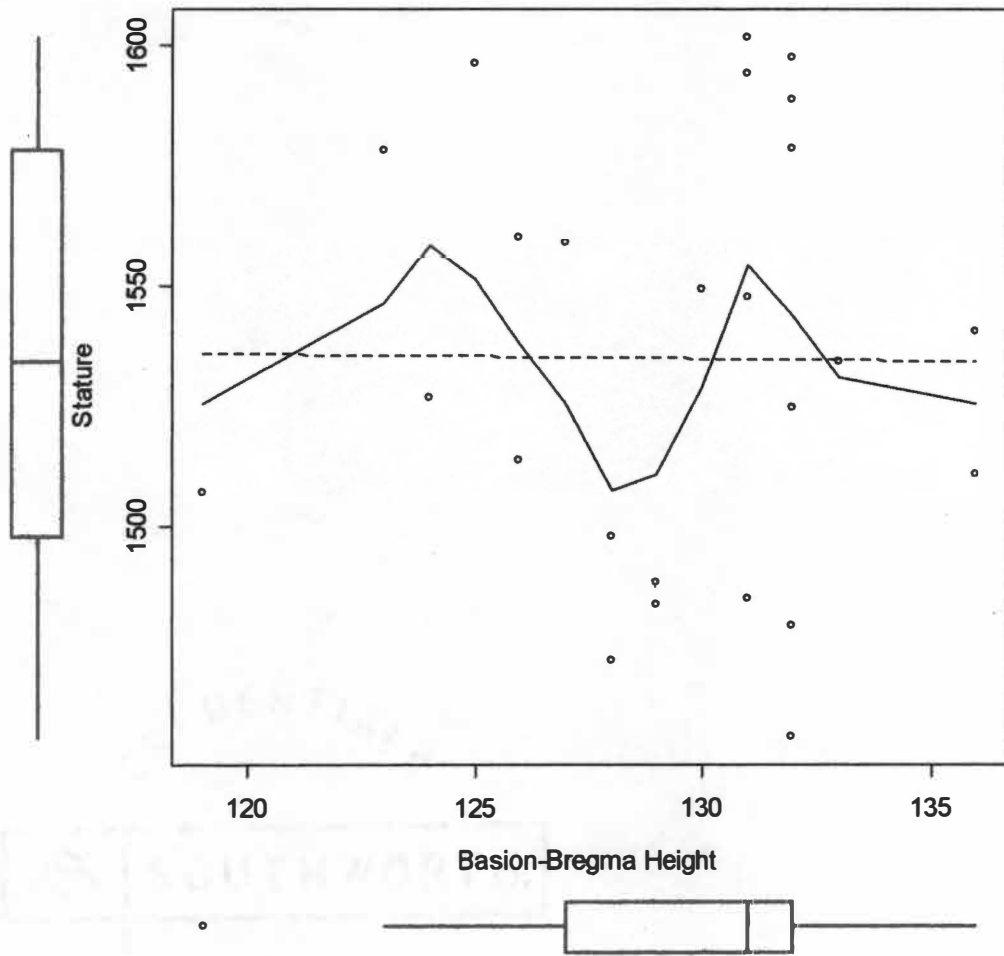


Figure 17. Females, Inverse Calibration, Stature Regressed on Basion-Bregma Height

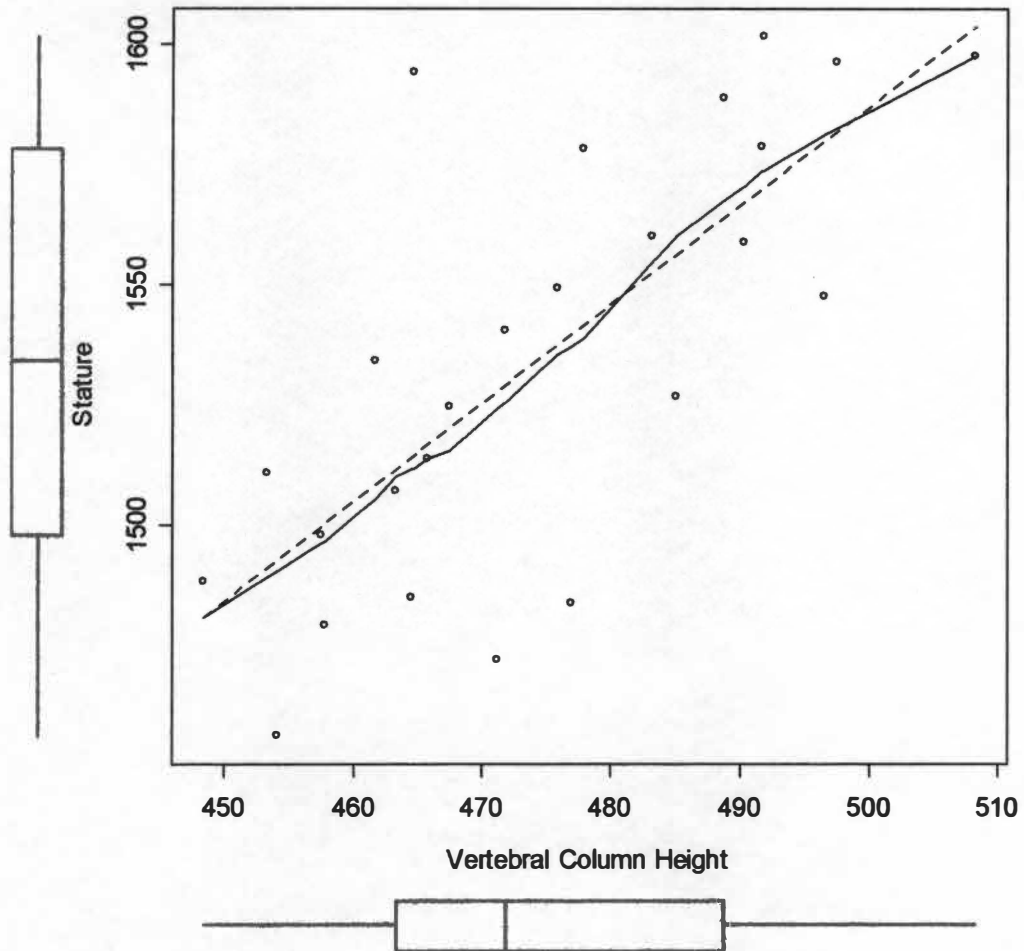


Figure 18. Females, Inverse Calibration, Stature Regressed on Vertebral Column Height

Stature regressed on Vertebral Column Height (VCH):

$$\text{Stature} = ((\text{VCH}) * 2.047) + 563.212 \pm 30.25164$$

F-statistic: 27.05

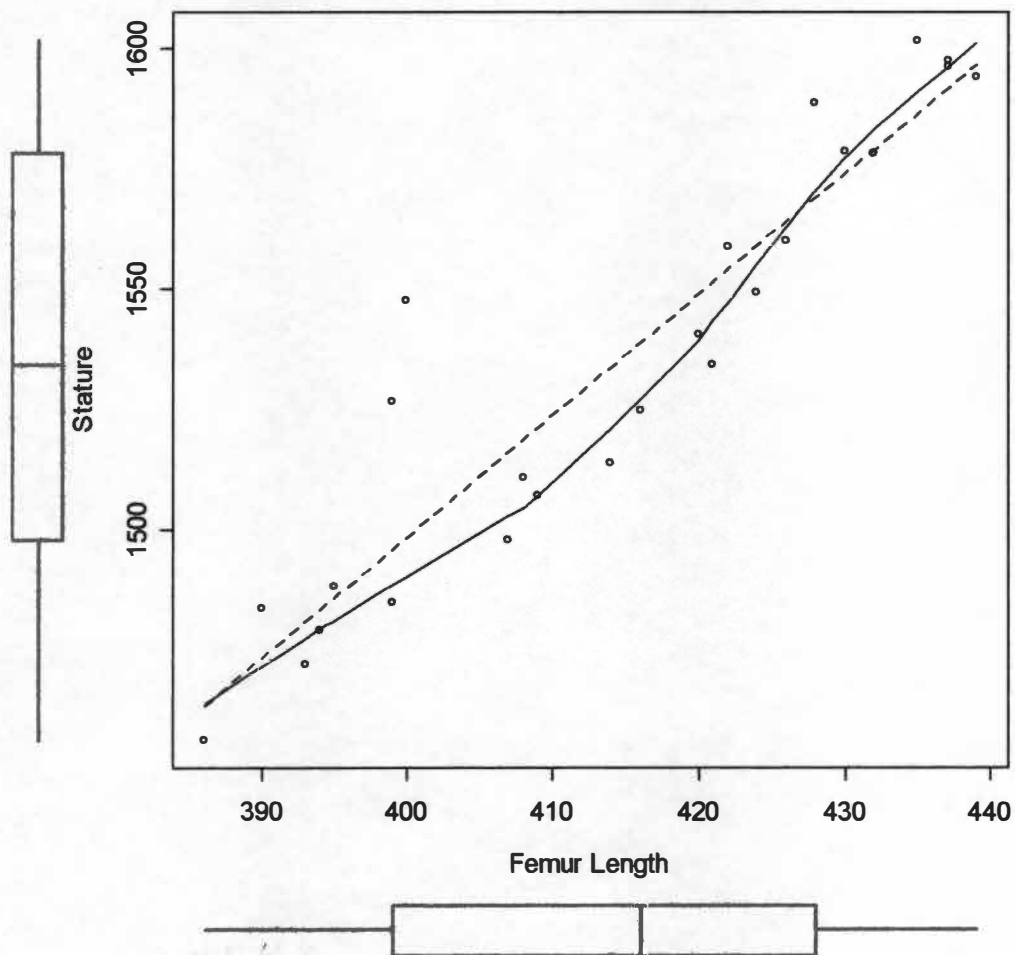


Figure 19. Females, Inverse Calibration, Stature Regressed on Bicondylar Femur Length

Stature regressed on Bicondylar Femur Length (BFL):

$$\text{Stature} = ((\text{BFL}) * 2.512) + 494.105 \pm 15.93868$$

F-statistic: 157.3

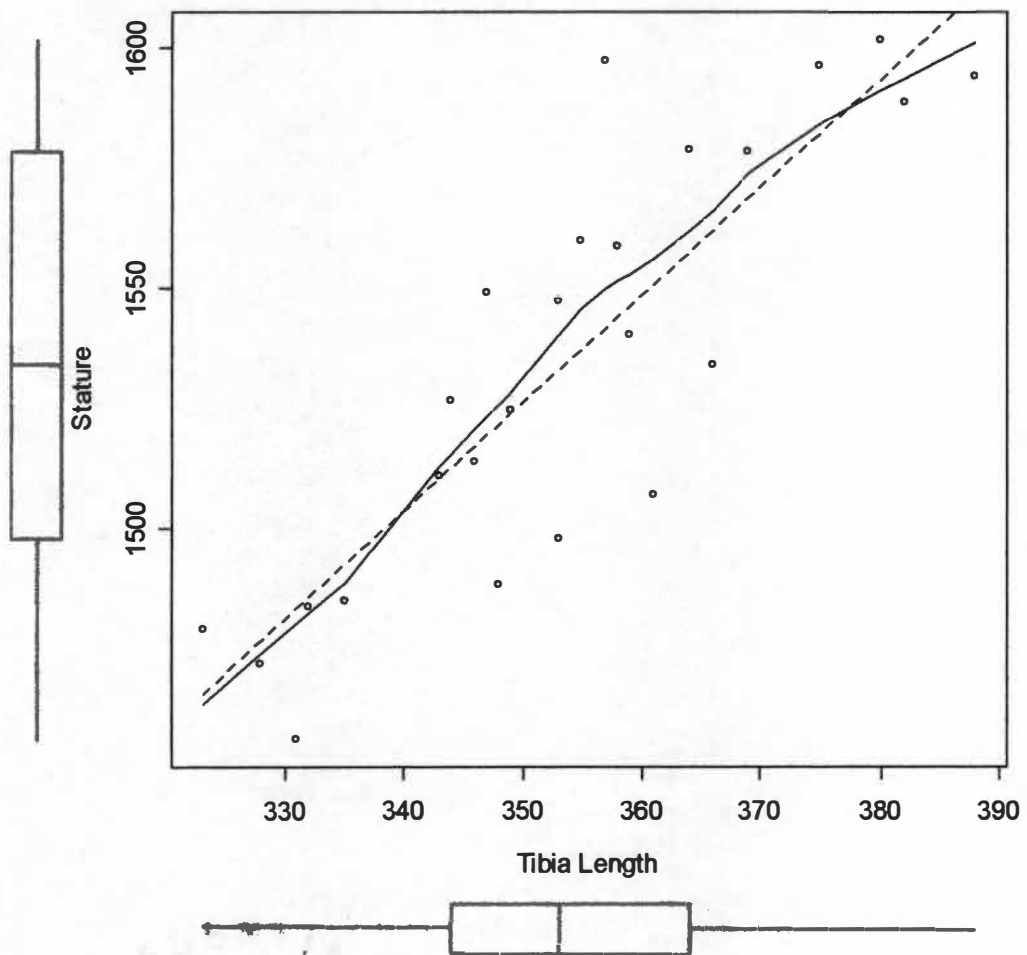


Figure 20. Females, Inverse Calibration, Stature Regressed on Condylar-Malleolar Tibia Length

Stature regressed on Condylar-Malleolar Tibia Length (CMTL):

$$\text{Stature} = ((\text{CMTL}) * 2.243) + 741.319 \pm 22.73677$$

F-statistic: 65.6

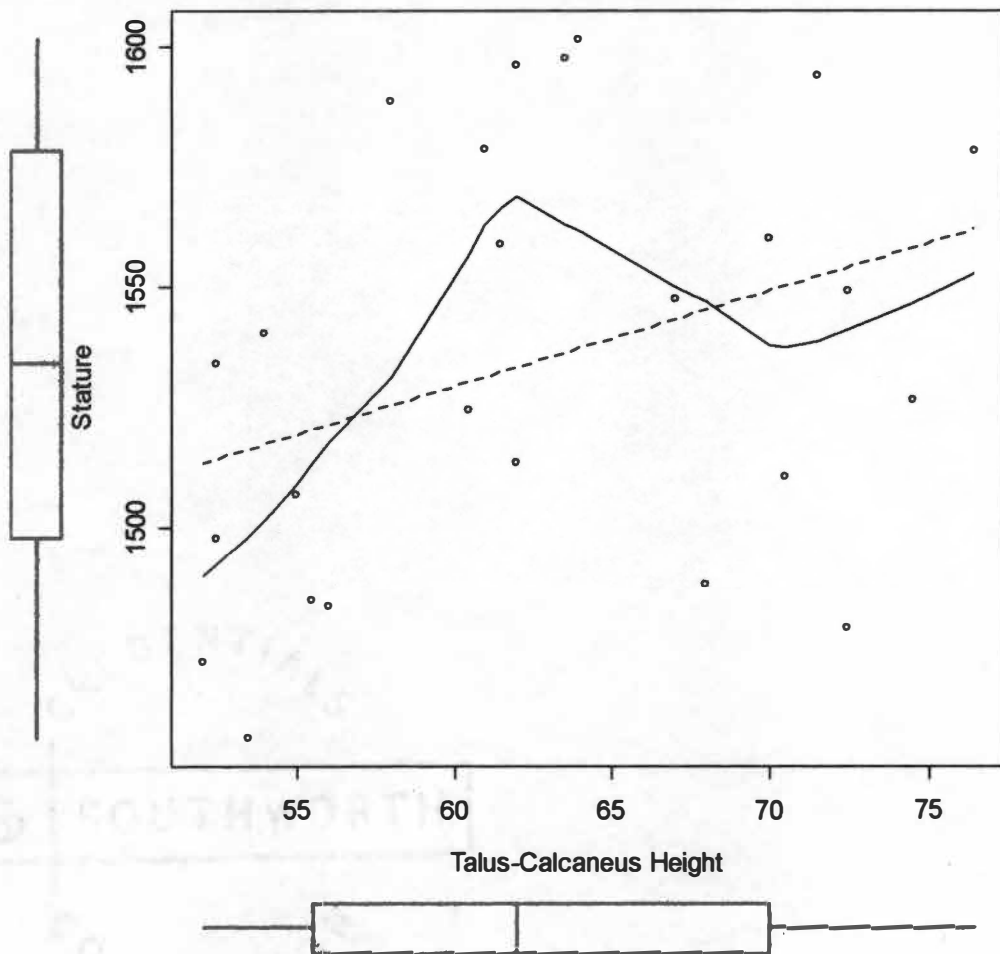


Figure 21. Females, Inverse Calibration, Stature Regressed on Articulated Height of the Talus and Calcaneus

Stature regressed on Articulated Talus-Calcanus Height (TCH):

$$\text{Stature} = ((\text{TCH}) * 1.979) + 1410.969 \pm 41.92143$$

F-statistic: 3.062

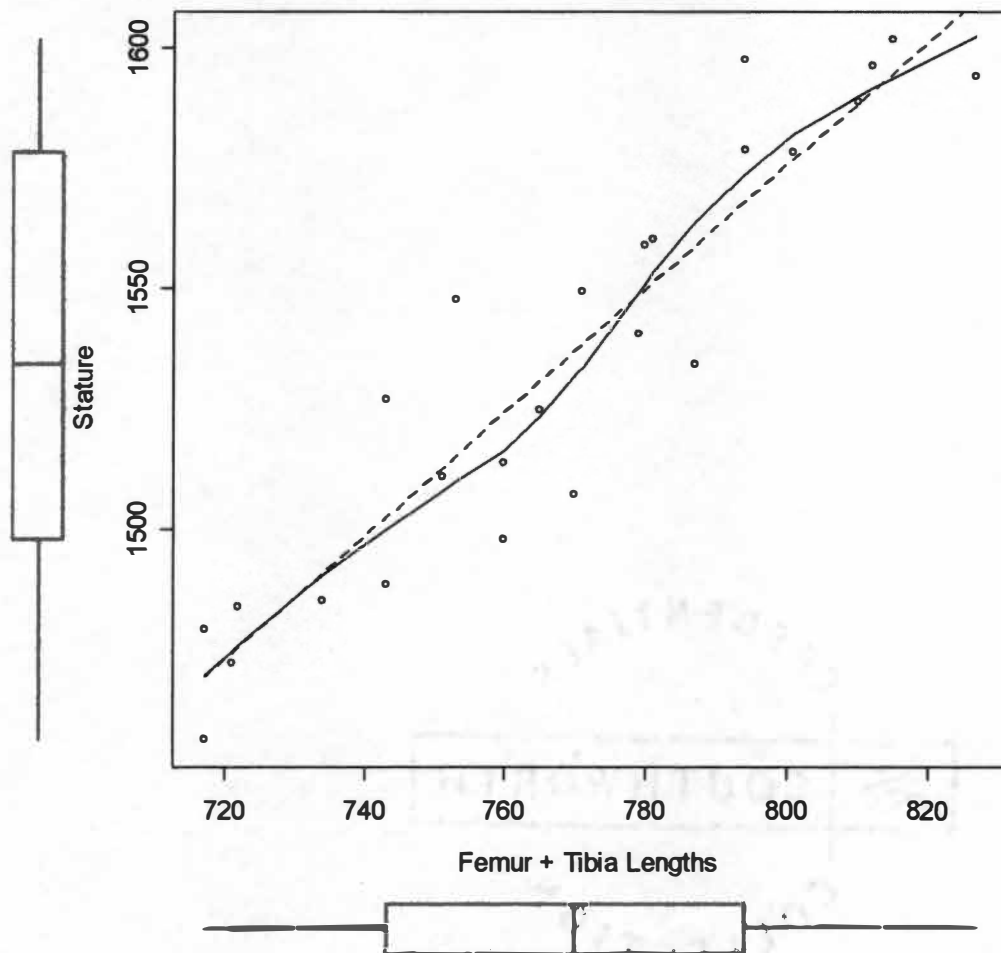


Figure 22. Females, Inverse Calibration, Stature Regressed on Combined Femur and Tibia Lengths

Stature regressed on Combined Femur and Tibia Lengths:

$$\text{Stature} = ((\text{BFL}) * 1.96) + ((\text{CMTL}) * 0.63) + 499.84 \pm 16.10876$$

F-statistic: 15.55

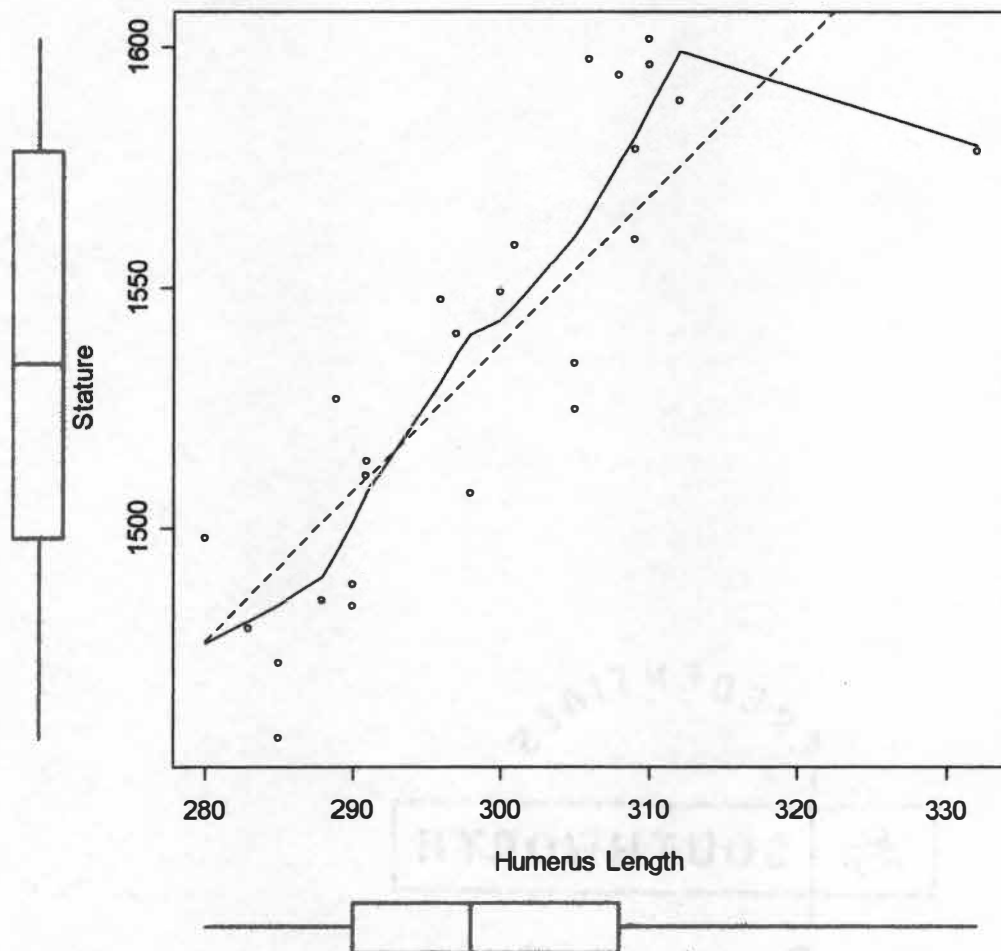


Figure 23. Females, Inverse Calibration, Stature Regressed on Maximum Humerus Length (HML)

Stature regressed on Humerus Length:

$$\text{Stature} = ((\text{HML}) * 3.089) + 612.145 \pm 24.983$$

F-statistic: 50.38

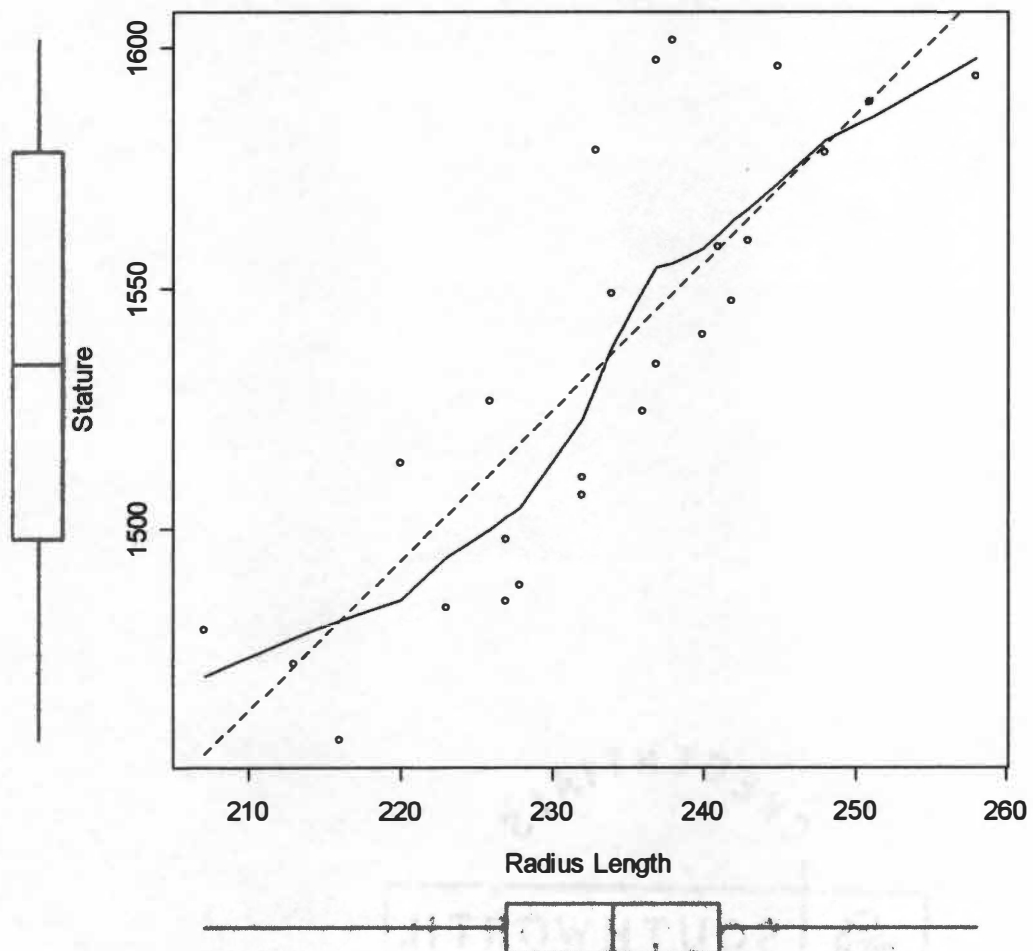


Figure 24. Females, Inverse Calibration, Stature Regressed on Maximum Radius Length (RML)

Stature regressed on Radius Length (RML):

$$\text{Stature} = ((\text{RML}) * 3.09) + 813.87 \pm 24.811$$

F-statistic: 51.4

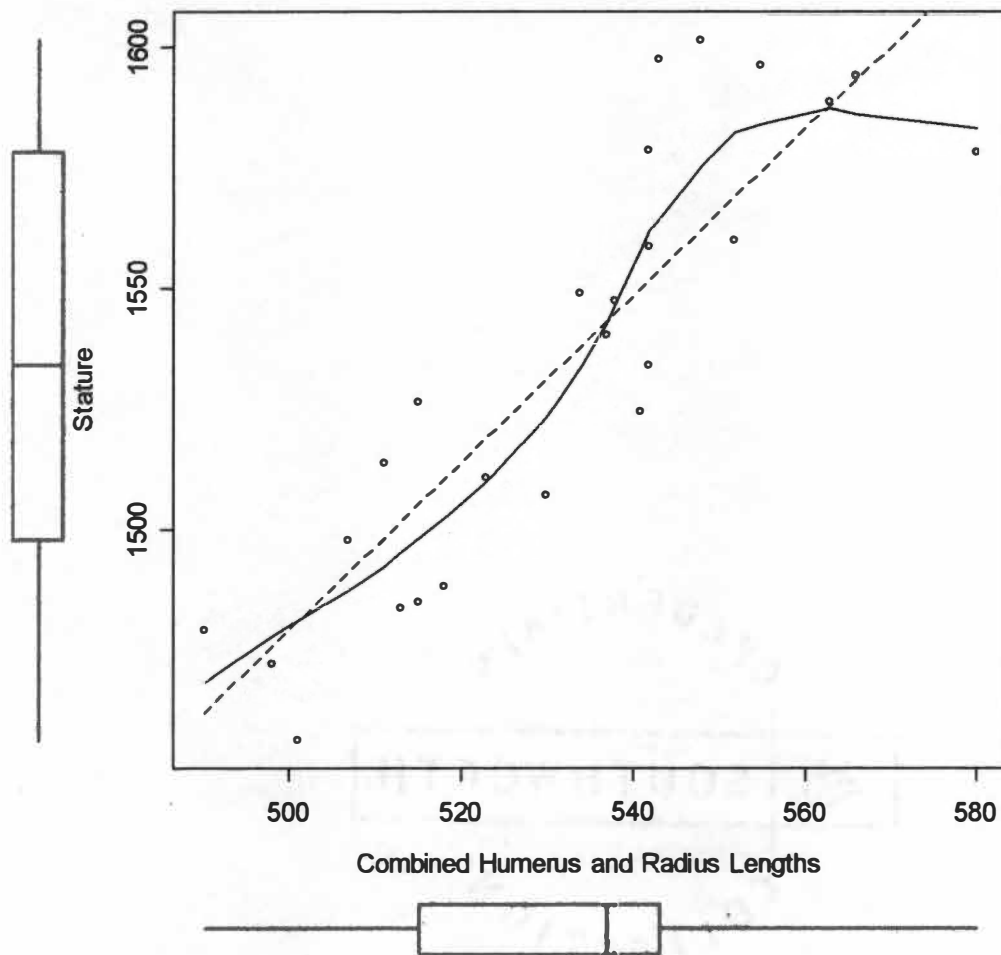


Figure 25. Females, Inverse Calibration. Stature Regressed on Combined Humerus and Radius Lengths

Stature regressed on Combined Humerus and Radius Lengths:

$$\text{Stature} = ((\text{HML}) * 1.706) + ((\text{RML}) * 1.748) + 617.335 \pm 21.403$$

F-statistic: 36.83

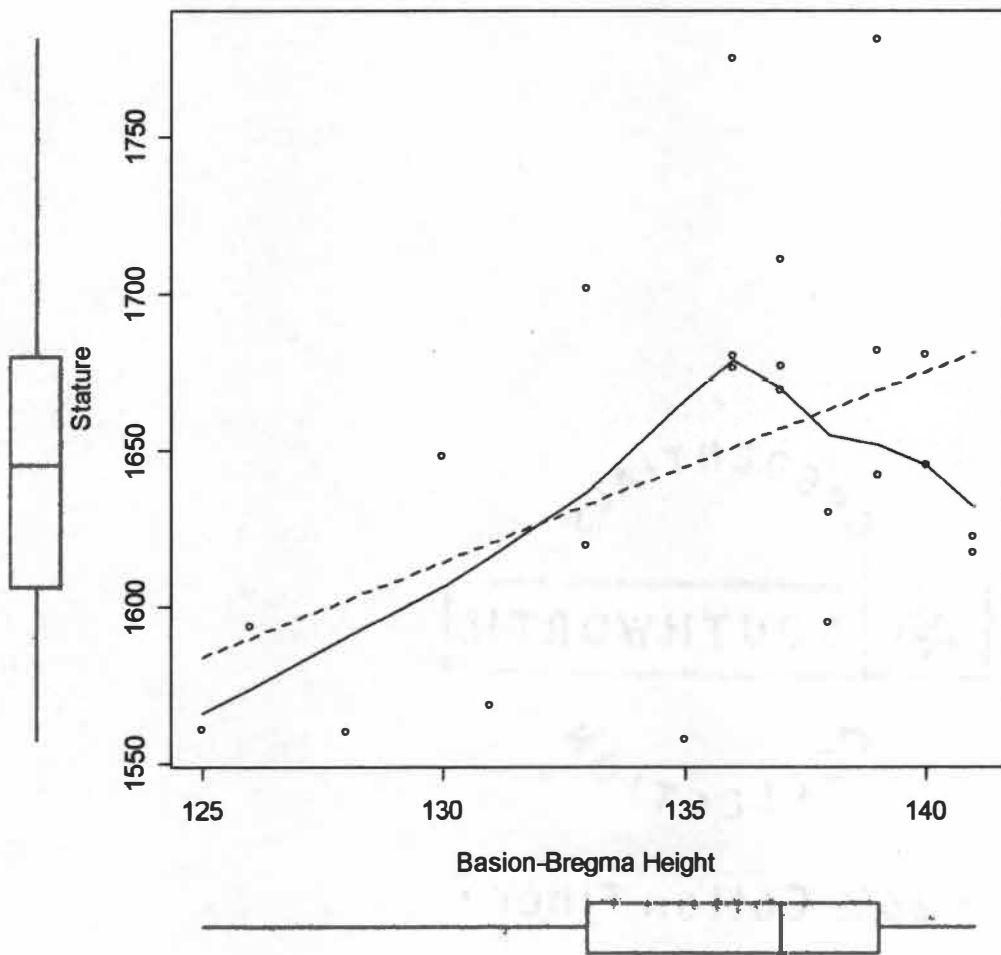


Figure 26. Males, Inverse Calibration, Stature Regressed on Basion-Bregma Height

Stature regressed on Basion-Bregma Height (BBH):

$$\text{Stature} = ((\text{BBH}) * 6.076) + 824.661 \pm 55.04056$$

F-statistic: 5.556

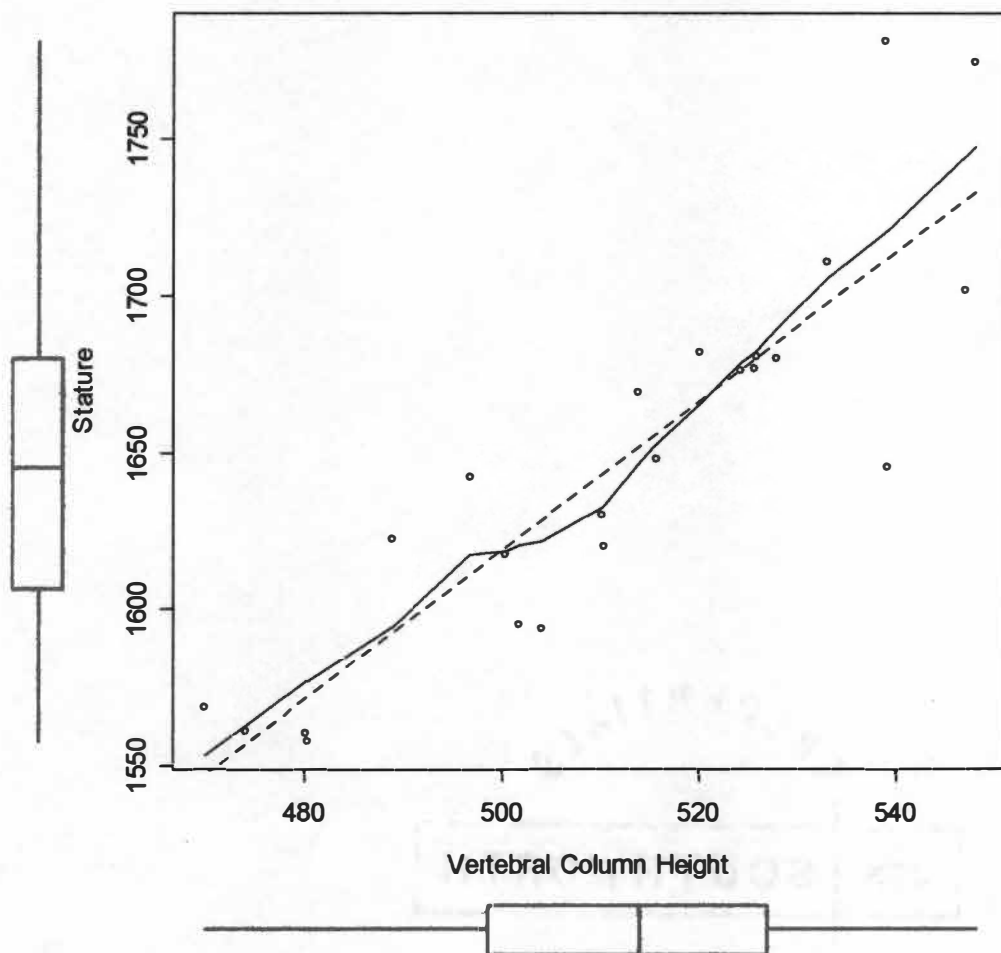


Figure 27. Males, Inverse Calibration, Stature Regressed on Vertebral Column Height

Stature regressed on Vertebral Column Height:

$$\text{Stature} = ((\text{VCH}) * 2.383) + 427.284 \pm 28.78438$$

F-statistic: 76.1

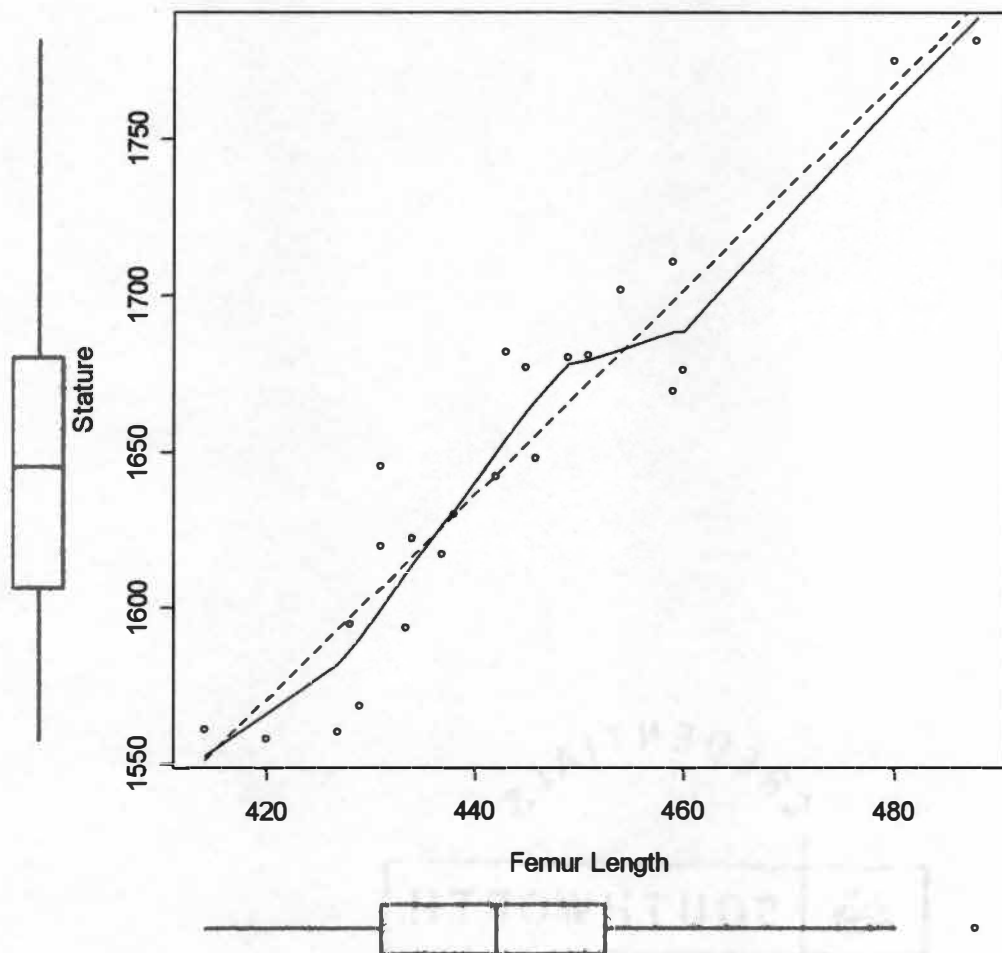


Figure 28. Males, Inverse Calibration, Stature Regressed on Bicondylar Femur Length

Stature regressed on Bicondylar Femur Length:

$$\text{Stature} = ((\text{BFL}) * 3.279) + 193.512 \pm 20.31662$$

F-statistic: 173.9

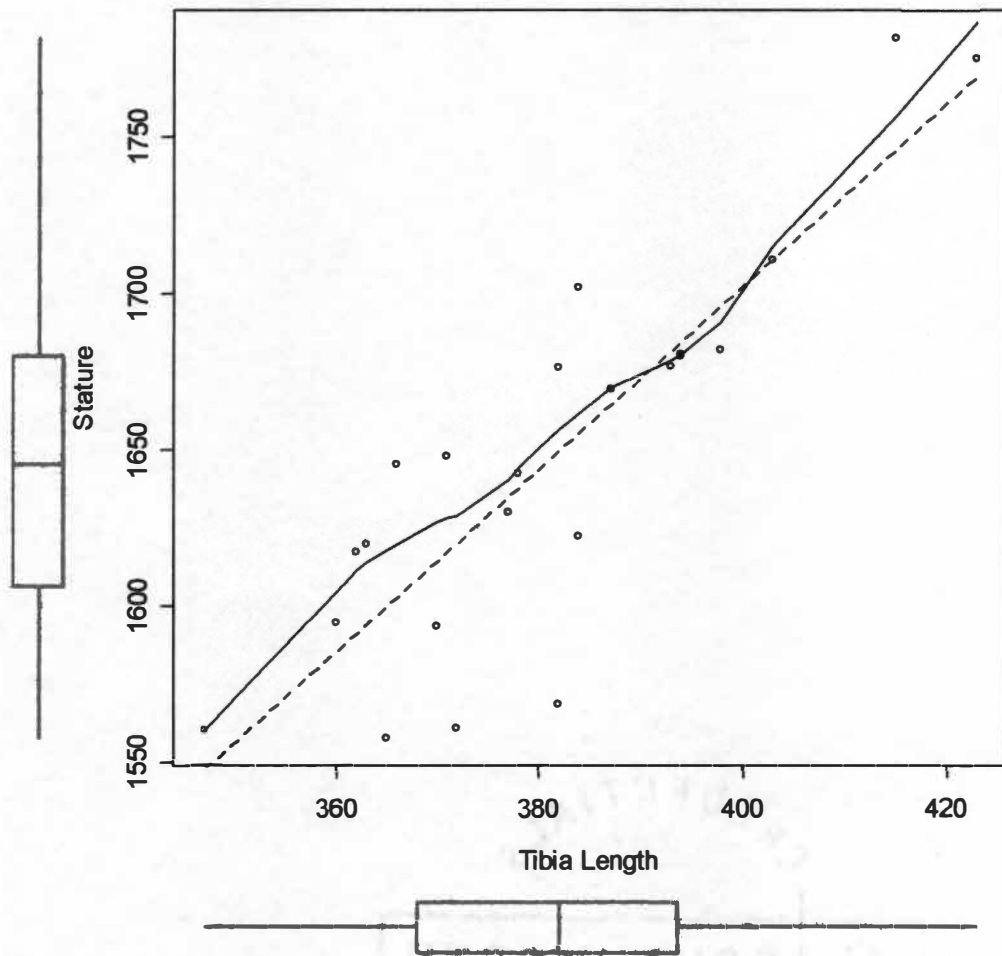


Figure 29. Males, Inverse Calibration, Stature Regressed on Condylar-Malleolar Tibia Length

Stature regressed on Condylar-Malleolar Tibia Length:

$$\text{Stature} = ((\text{CMTL}) * 2.913) + 536.816 \pm 31.74951$$

F-statistic: 58.81

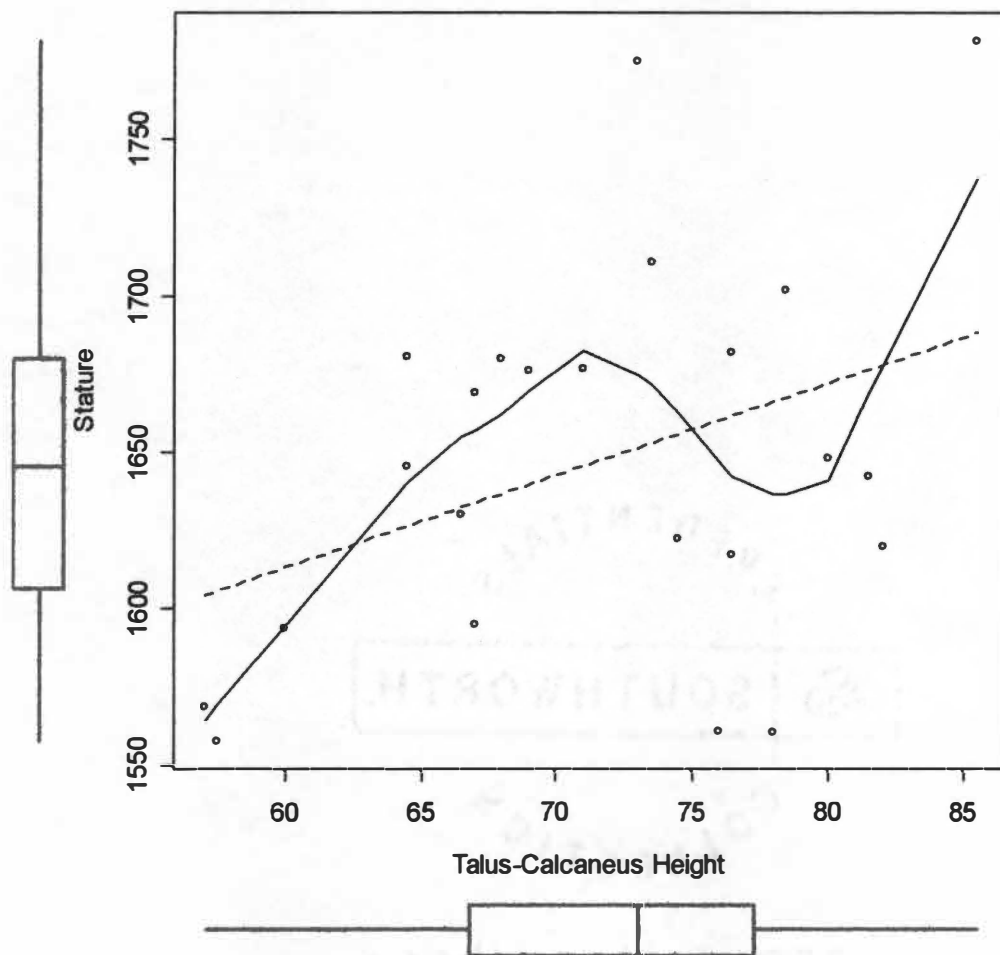


Figure 30. Males, Inverse Calibration, Stature Regressed on Articulated Height of the Talus and Calcaneus

Stature regressed on Articulated Talus-Calcanus Height:

$$\text{Stature} = ((\text{TCH}) * 2.938) + 1437.103 \pm 57.36928$$

F-statistic: 3.444

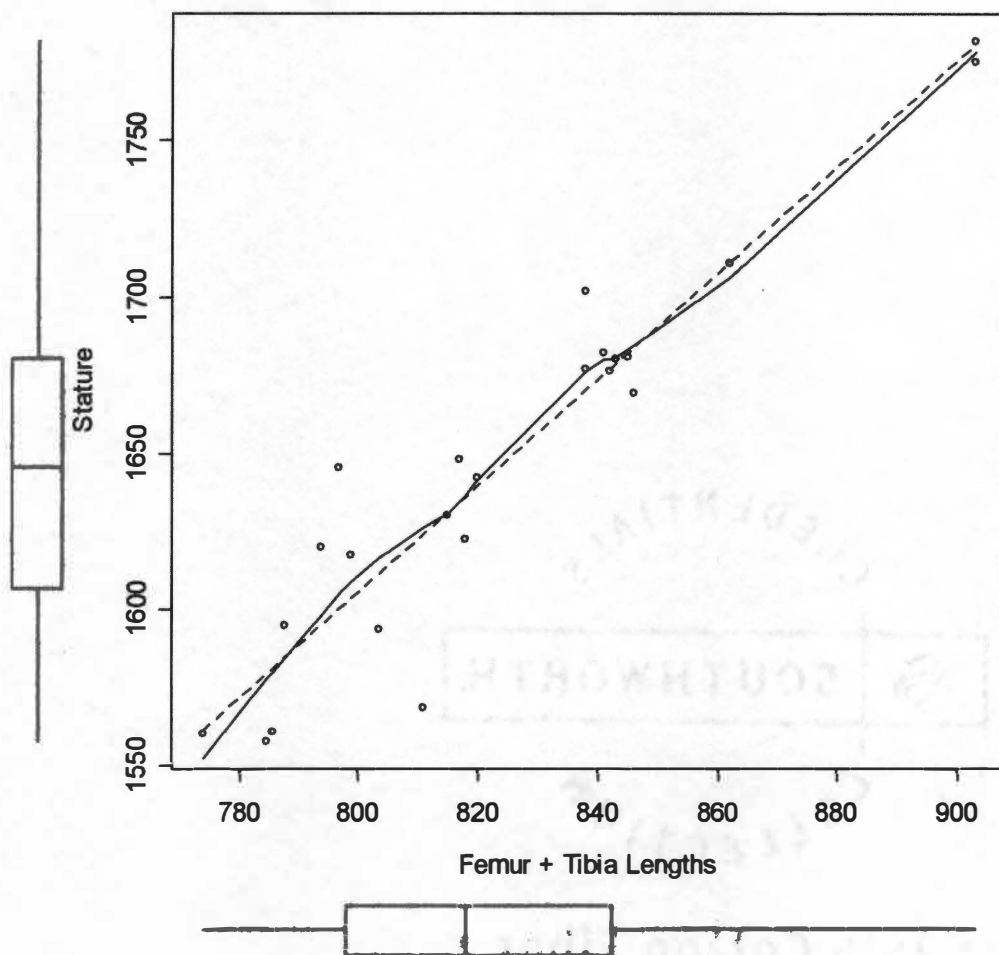


Figure 31. Males, Inverse Calibration, Stature Regressed on Combined Femur and Tibia Lengths

Stature regressed on Combined Femur and Tibia Lengths:

$$\text{Stature} = ((\text{BFL}) * 2.5372) + ((\text{CMTL}) * 0.8886)) + 183.6989 \pm 20.15639$$

F-statistic: 87.87

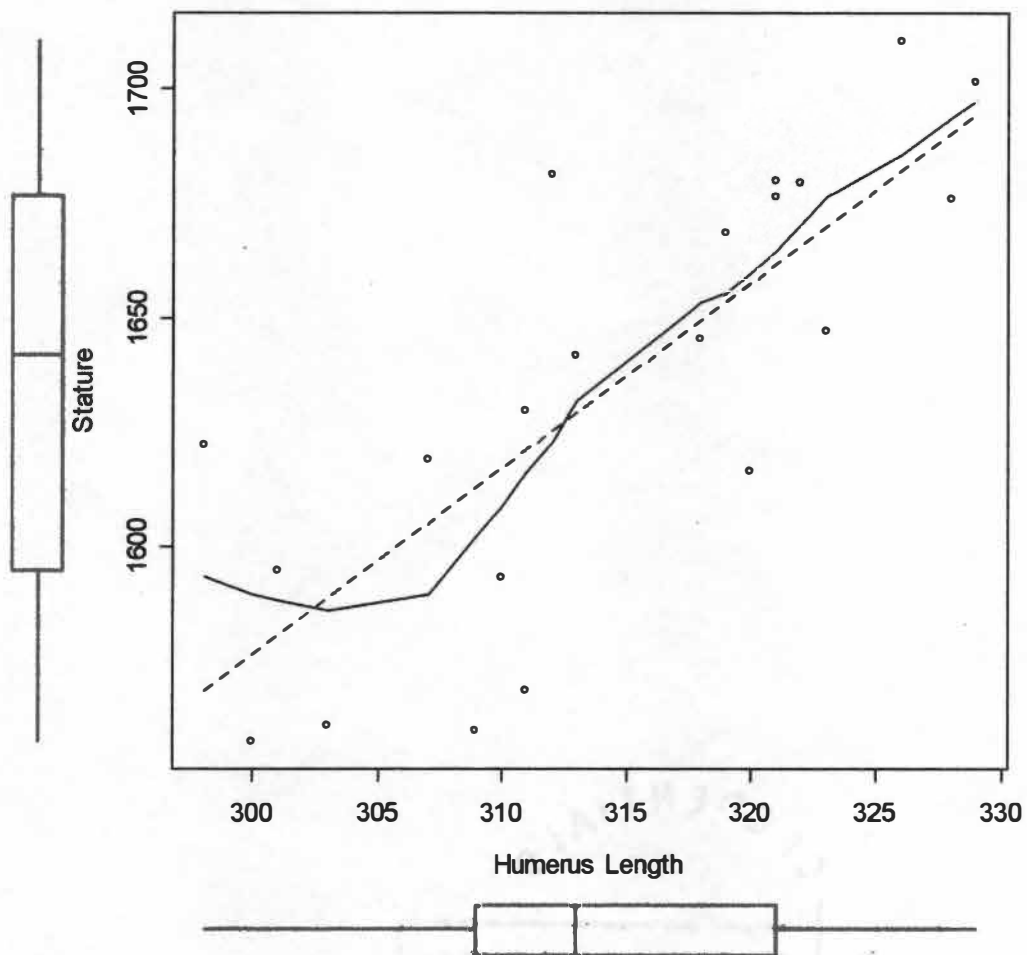
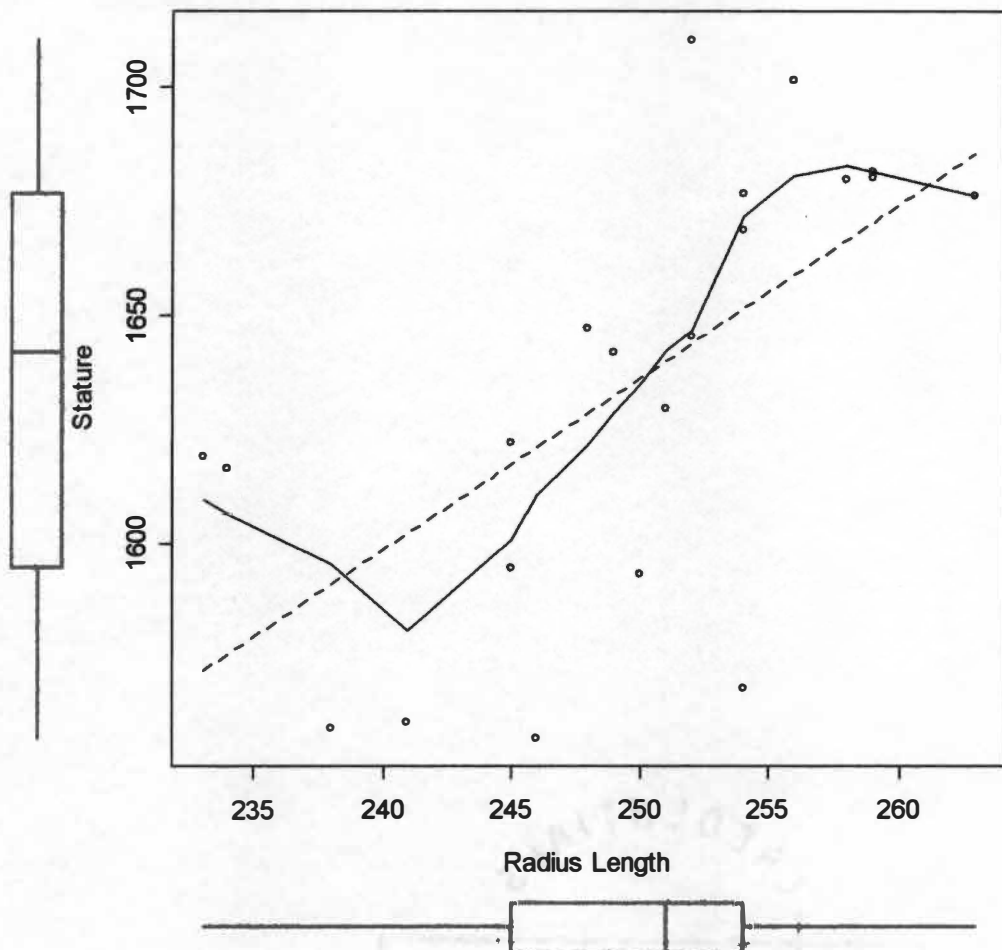


Figure 32. Males, Inverse Calibration, Stature Regressed on Maximum Humerus Length

Stature regressed on Humerus Length:

$$\text{Stature} = ((\text{HML}) * 4.06) + 358.72 \pm 30.189$$

F-statistic: 29.84



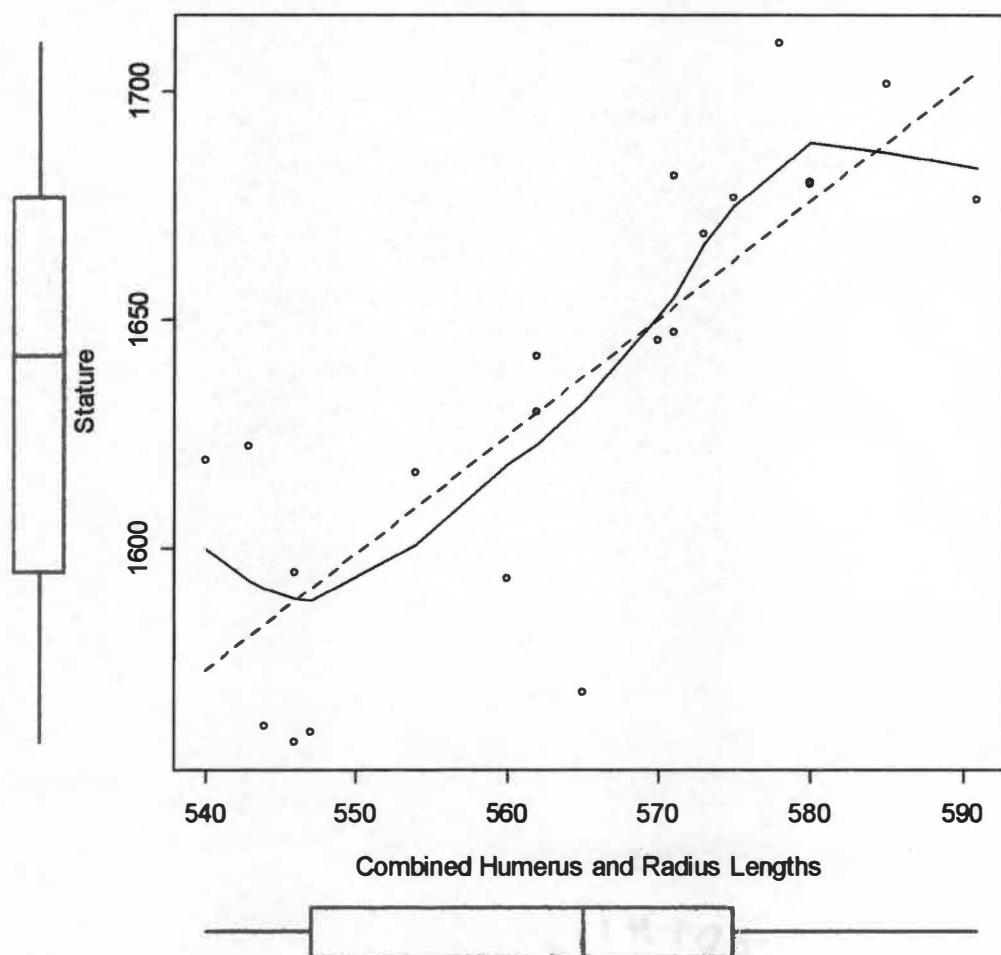


Figure 34. Males, Inverse Calibration, Stature Regressed on Combined Humerus and Radius Lengths

Stature regressed on Combined Humerus and Radius Lengths:

$$\text{Stature} = ((\text{HML}) * 3.225) + ((\text{RML}) * 1.779)) + 177.306 \pm 28.263$$

F-statistic: 18.66

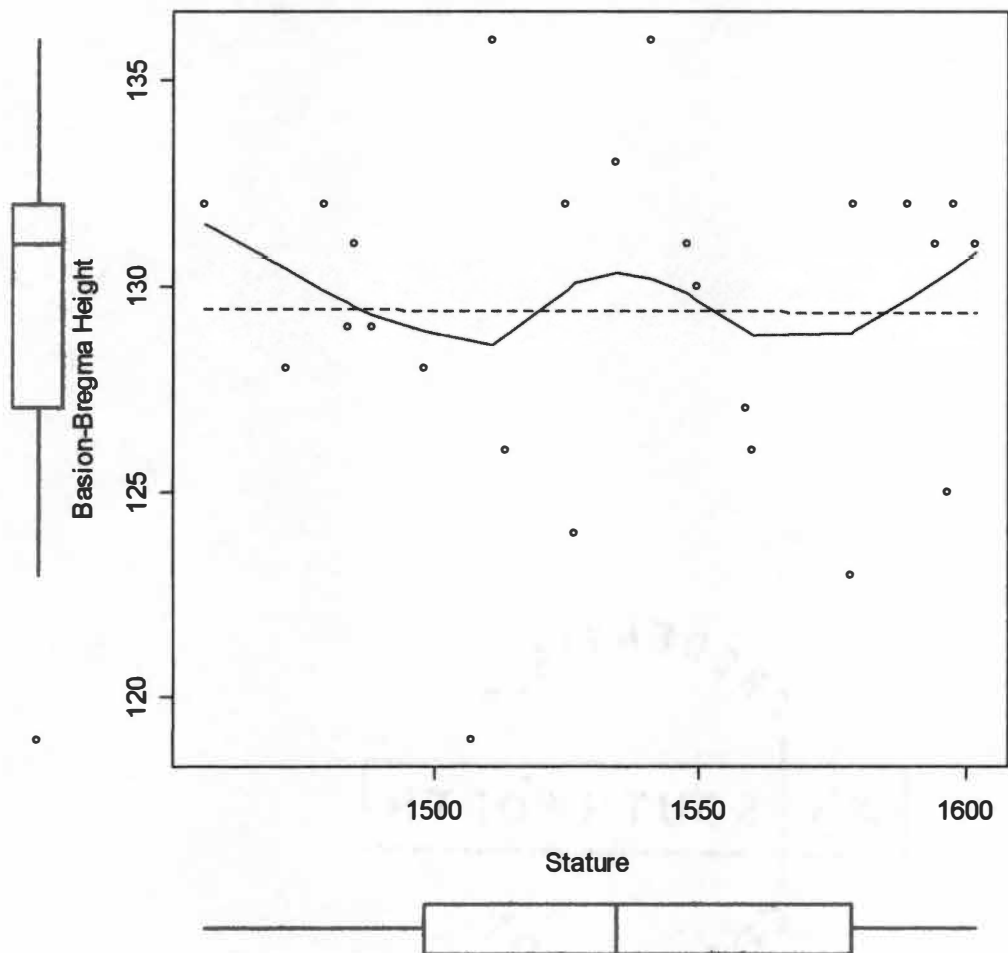


Figure 35. Females, Classic Calibration, Basion-Bregma Height Regressed on Stature

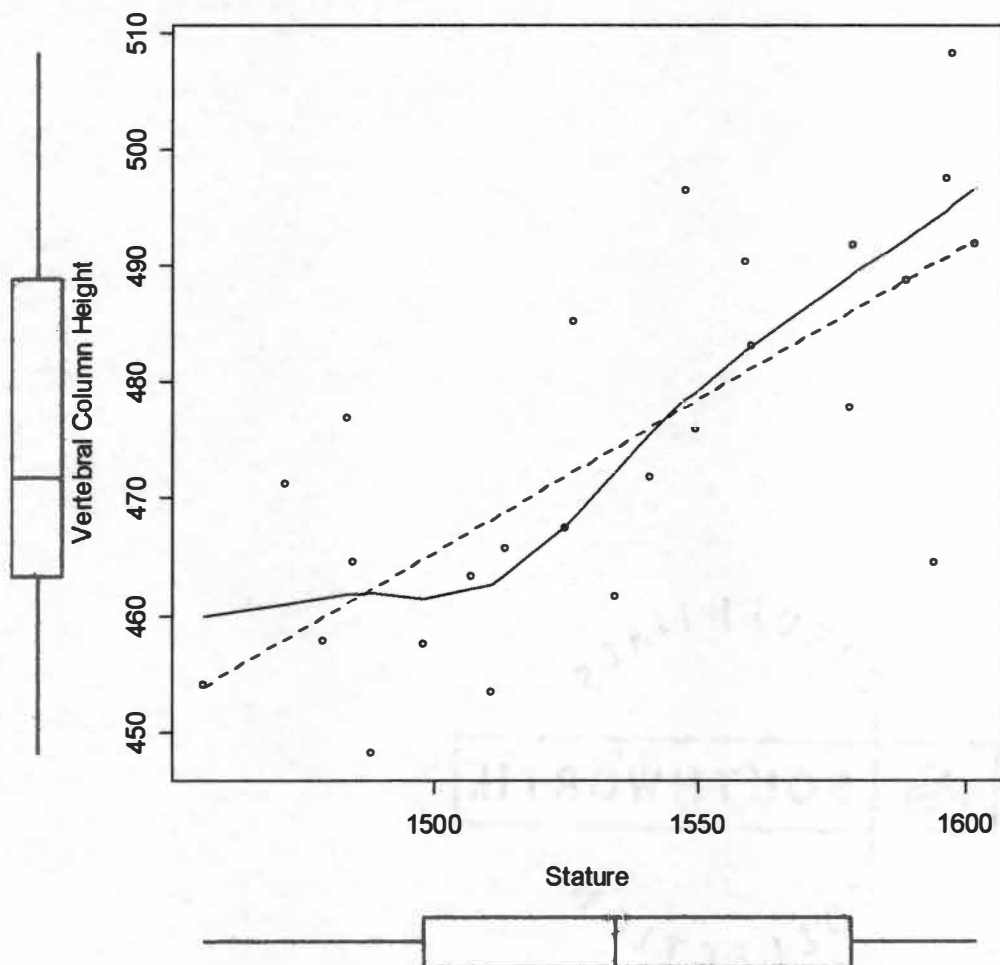


Figure 36. Females, Classic Calibration, Vertebral Column Height Regressed on Stature

Vertebral Column Height regressed on Stature:

$$\text{Stature} = ((\text{VCH}) * 3.7879) - 263.11 \pm 41.15053$$

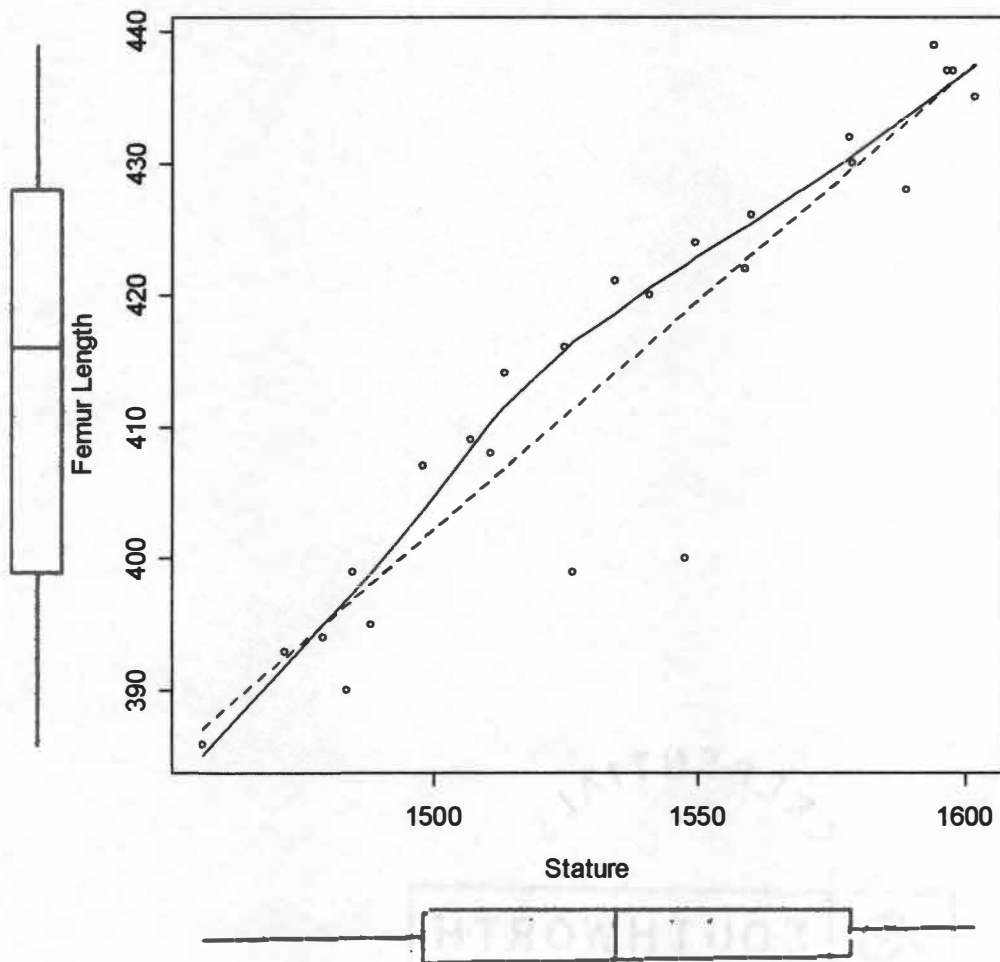


Figure 37. Females, Classic Calibration, Bicondylar Femur Length Regressed on Stature

Bicondylar Femur Length regressed on Stature:

$$\text{Stature} = ((\text{BFL}) * 2.8785) + 341.87 \pm 17.06424$$

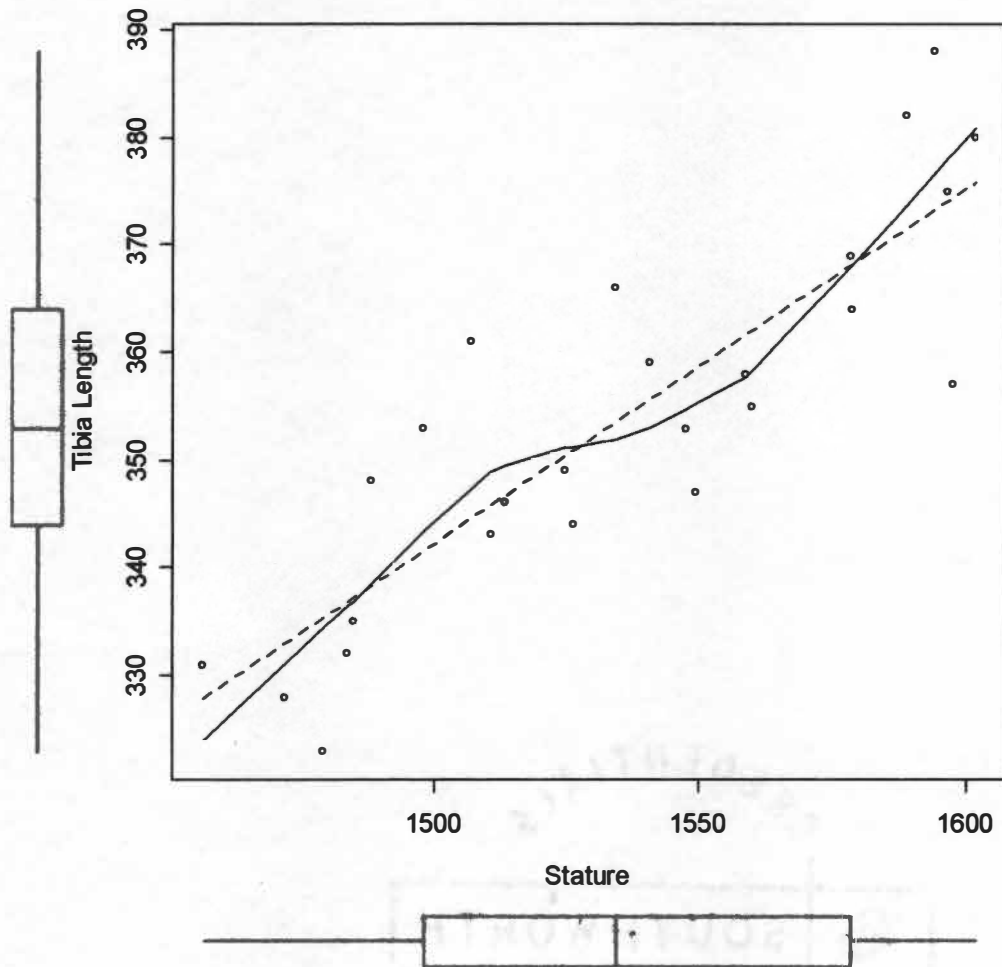


Figure 38. Females, Classic Calibration, Condylar-Malleolar Tibia Length Regressed on Stature

Condylar-Malleolar Tibia Length regressed on Stature:

$$\text{Stature} = ((\text{CMTL}) * 3.0294) + 463.03 \pm 26.4238$$

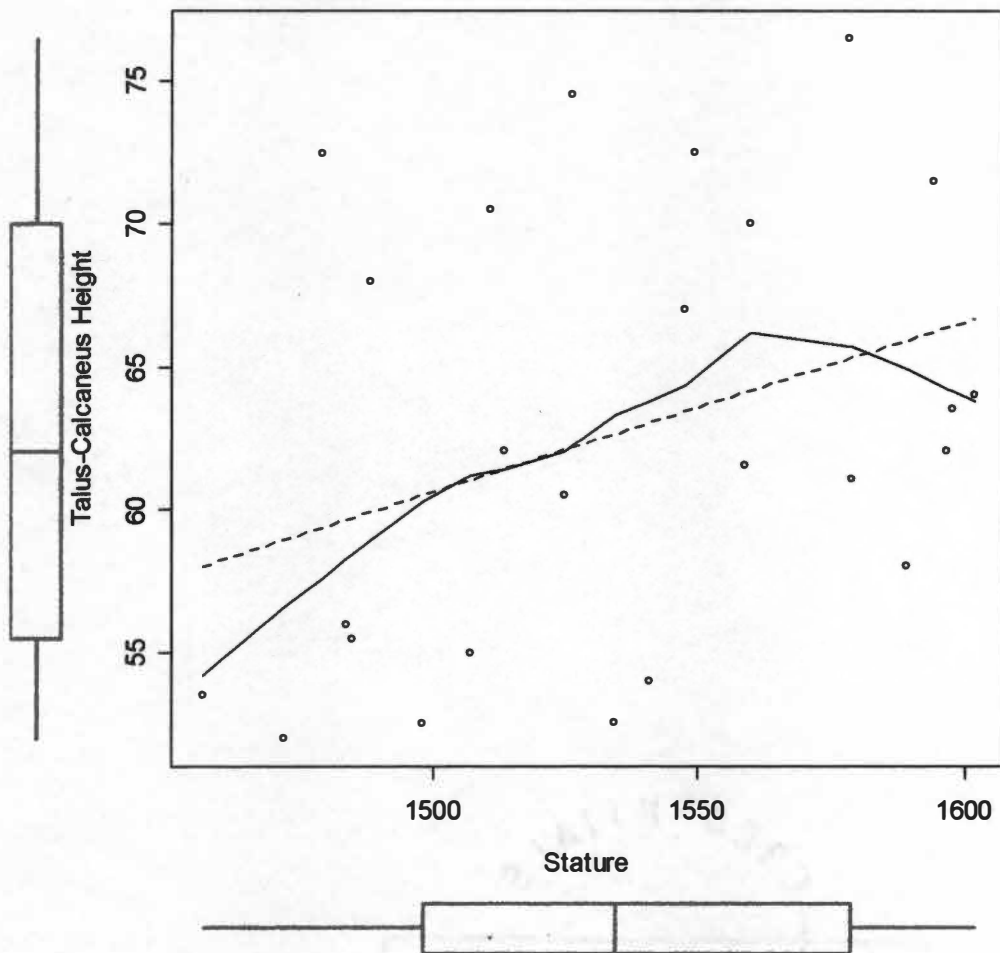


Figure 39. Females, Classic Calibration, Articulated Height of the Talus and Calcaneus Regressed on Stature

Articulated Talus-Calcanes Height regressed on Stature:

$$\text{Stature} = ((\text{TCH}) * 16.8464 + 479.43 \pm 122.3003$$

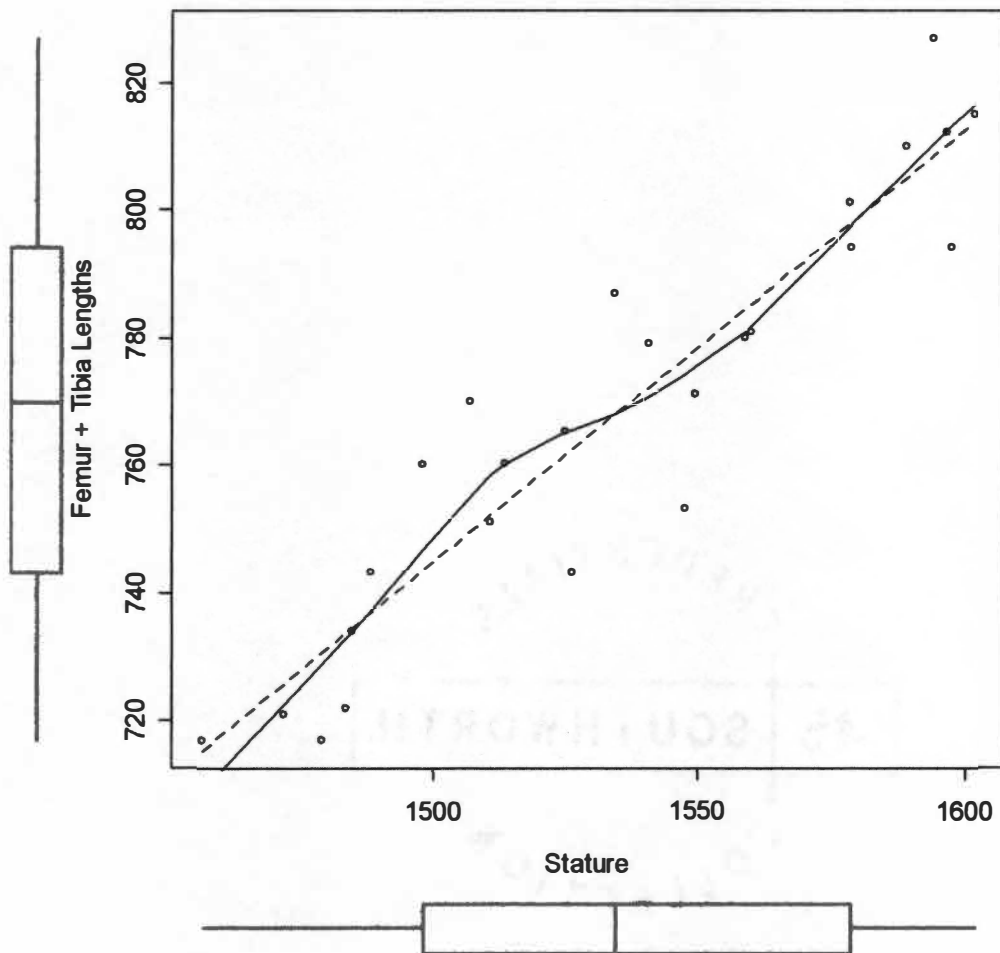


Figure 40. Females, Classic Calibration, Combined Femur and Tibia Lengths Regressed on Stature

Combined Femur and Tibia Lengths regressed on Stature:

$$\text{Stature} = ((\text{BFL} + \text{CMTL}) * 1.47601) + 400.901 \pm 17.27346$$

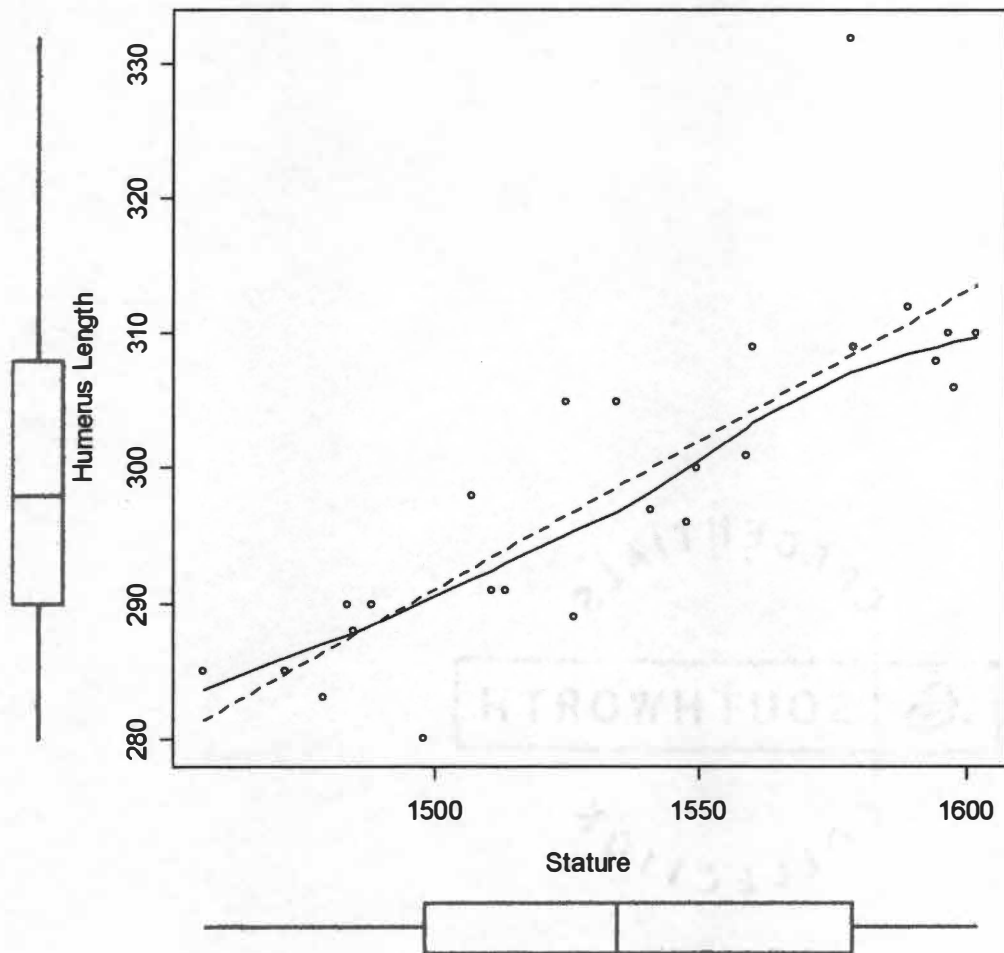


Figure 41. Females, Classic Calibration, Maximum Humerus Length Regressed on Stature

Humerus Length regressed on Stature:

$$\text{Stature} = ((\text{HML}) * 4.498) + 190.87 \pm 30.151$$

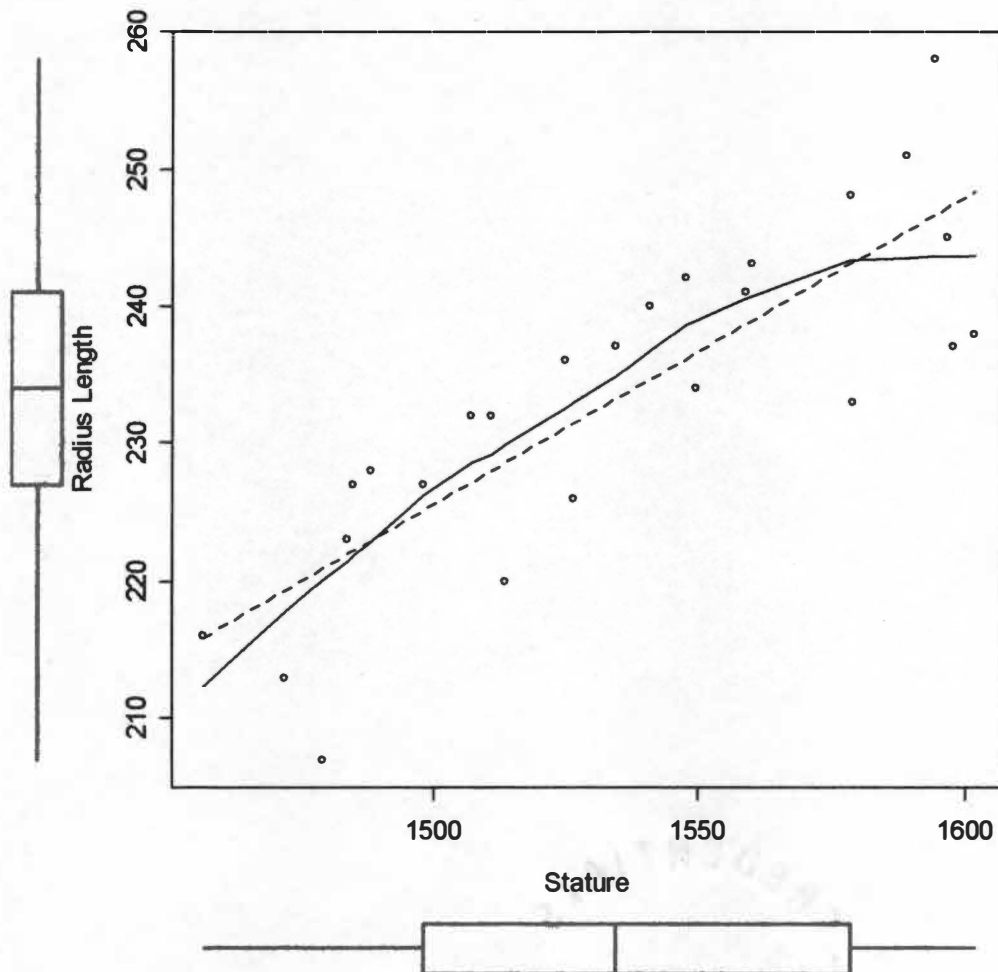


Figure 42. Females, Classic Calibration, Maximum Radius Length Regressed on Stature

Radius Length regressed on Stature:

$$\text{Stature} = ((\text{RML}) * 4.472) + 491.14 \pm 29.850$$

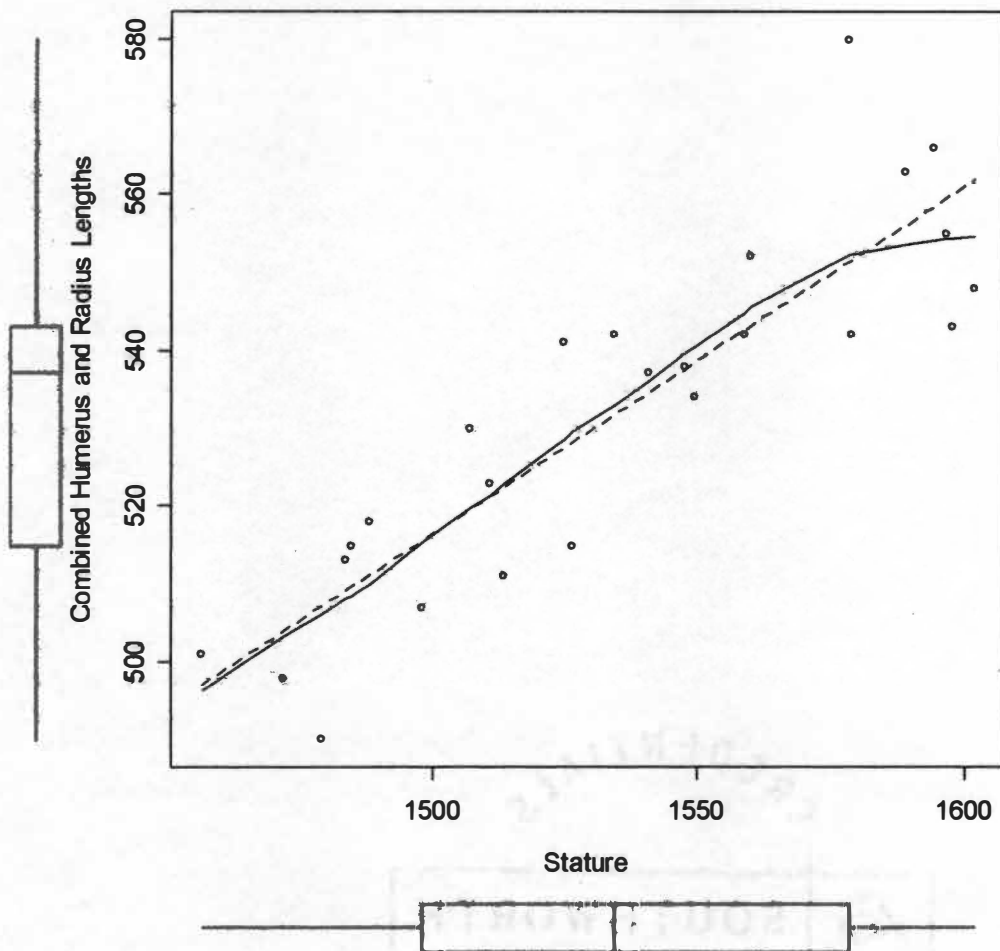


Figure 43. Females, Classic Calibration, Combined Humerus and Radius Lengths Regressed on Stature

Combined Humerus and Radius Lengths regressed on Stature:

$$\text{Stature} = ((\text{RML} + \text{HML}) * 2.243) + 341.44 \pm 24.389$$

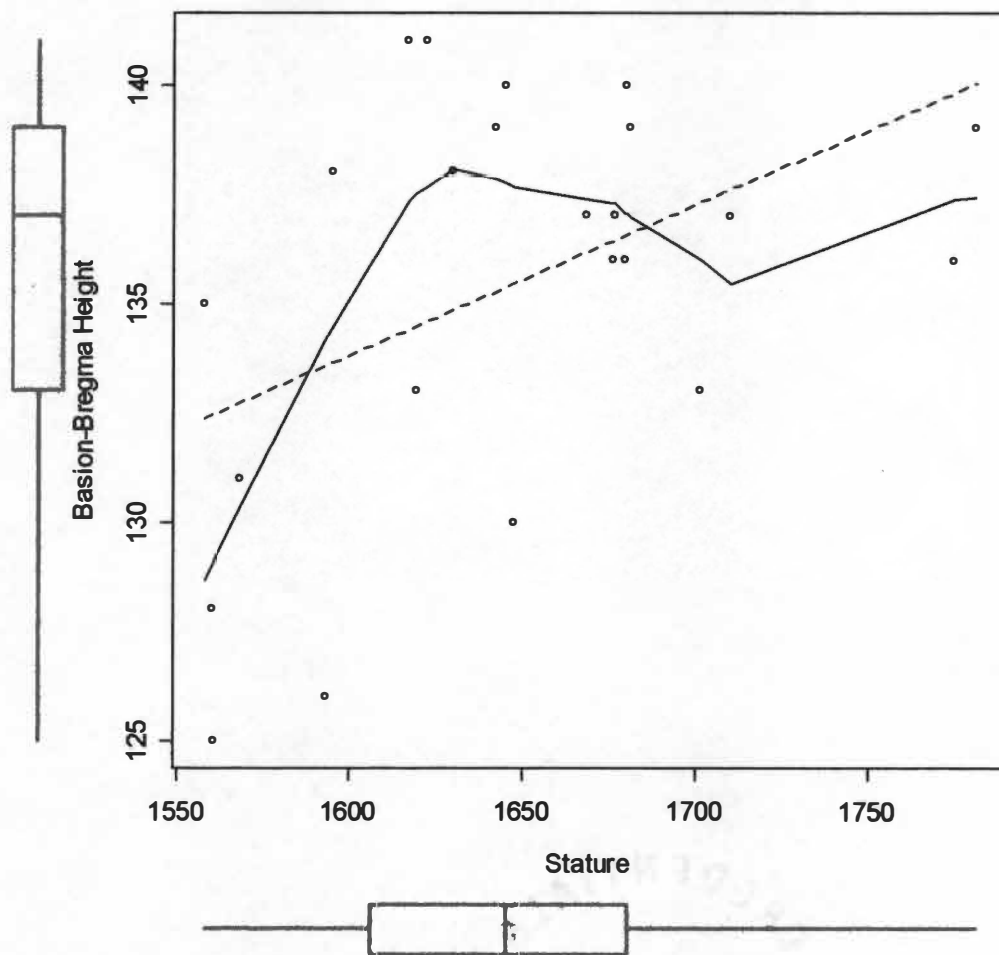


Figure 44. Males, Classic Calibration, Basion-Bregma Height Regressed on Stature

Basion-Bregma Height regressed on Stature:

$$\text{Stature} = ((\text{BBH}) * 29.0444) - 2285.853 \pm 120.3311$$

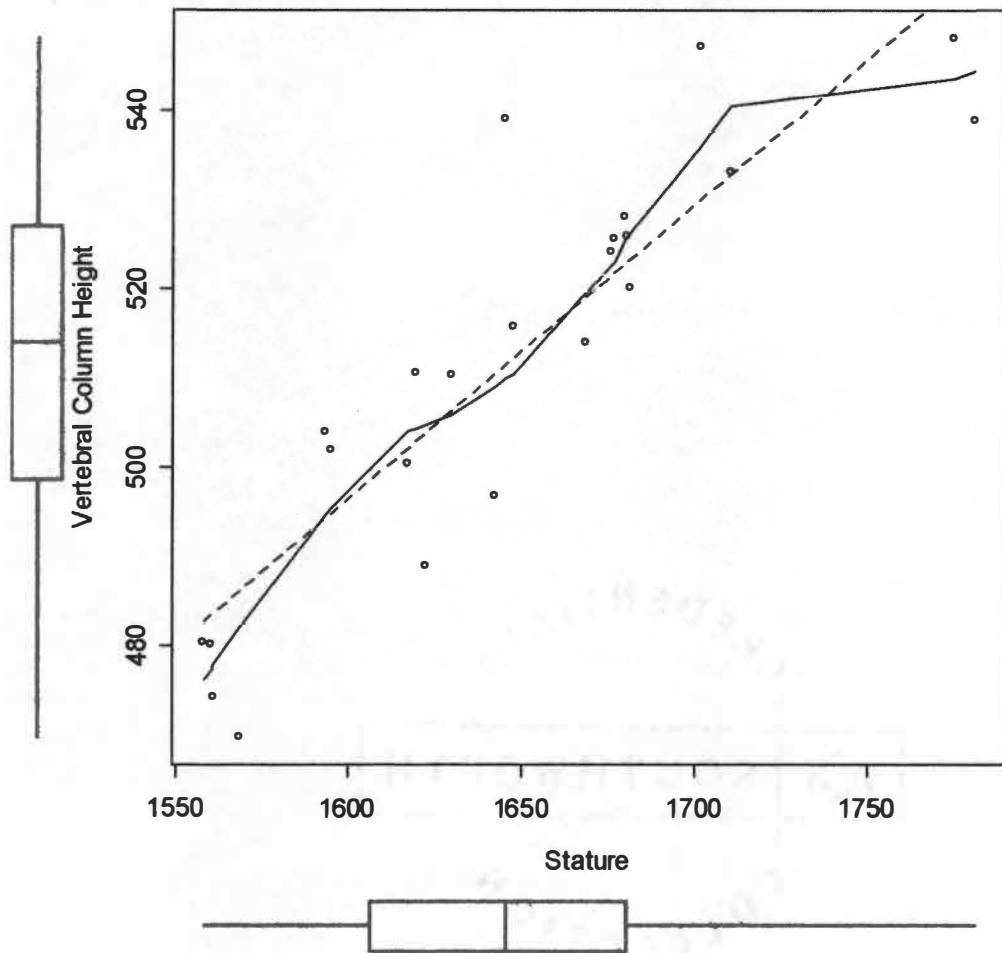


Figure 45. Males, Inverse Calibration, Vertebral Column Height Regressed on Stature

Vertebral Column Height regressed on Stature:

$$\text{Stature} = ((\text{VCH}) * 3.0404) + 90.5406 \pm 32.5143$$

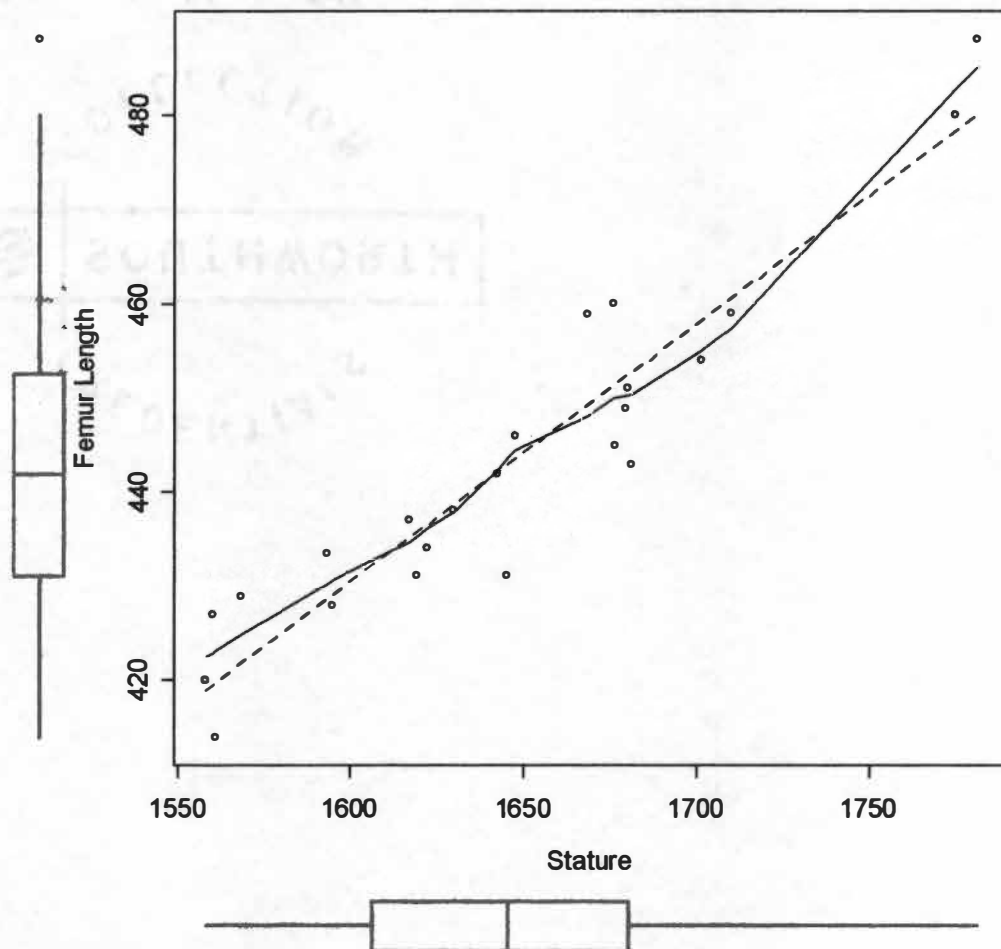


Figure 46. Males, Inverse Calibration, Bicondylar Femur Length Regressed on Stature

Bicondylar Femur Length regressed on Stature:

$$\text{Stature} = ((\text{BFL}) * 3.6751) + 17.9294 \pm 21.50832$$

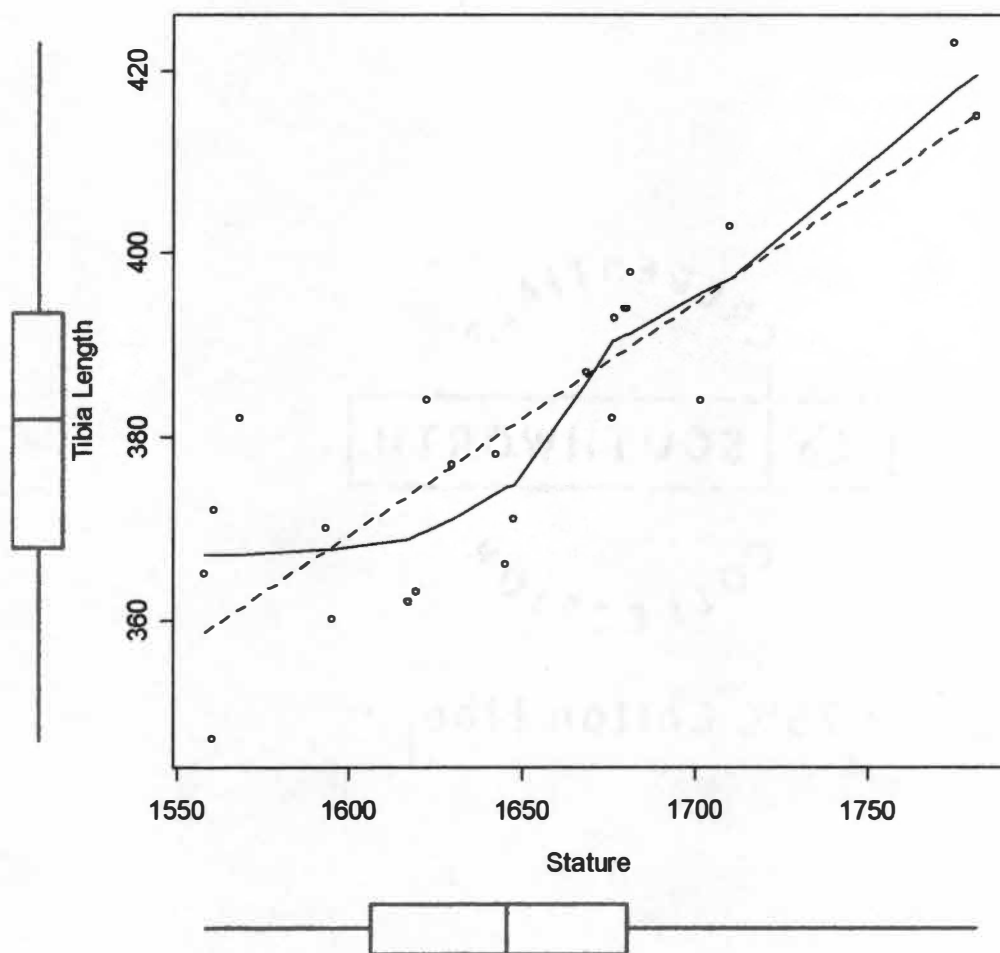


Figure 47. Males, Inverse Calibration, Condylar-Malleolar Tibia Length Regressed on Stature

Condylar-Malleolar Tibia Length regressed on Stature:

$$\text{Stature} = ((\text{CMTL}) * 3.9526) + 140.166 \pm 36.98624$$

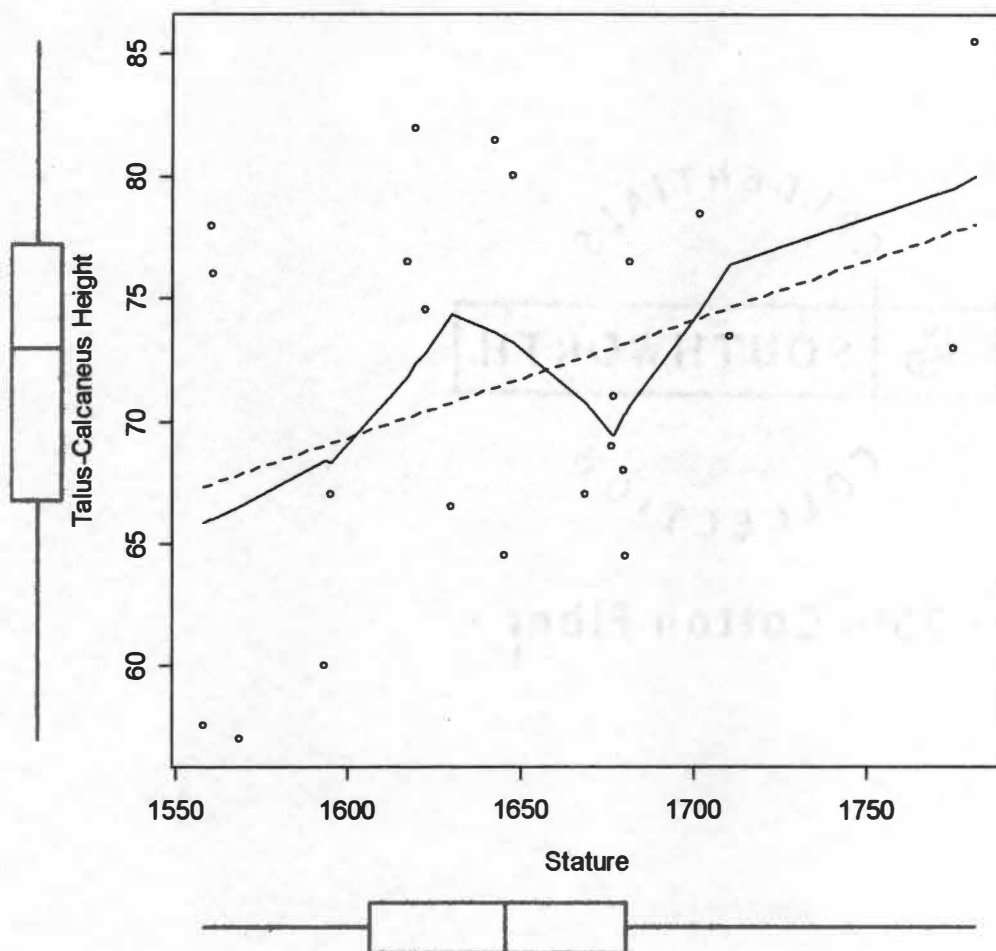


Figure 48. Males, Inverse Calibration, Articulated Height of the Talus and Calcaneus Regressed on Stature

Articulated Talus-Calcanus Height regressed on Stature:

$$\text{Stature} = ((\text{TCH}) * 20.8551) + 153.843 \pm 152.8390$$

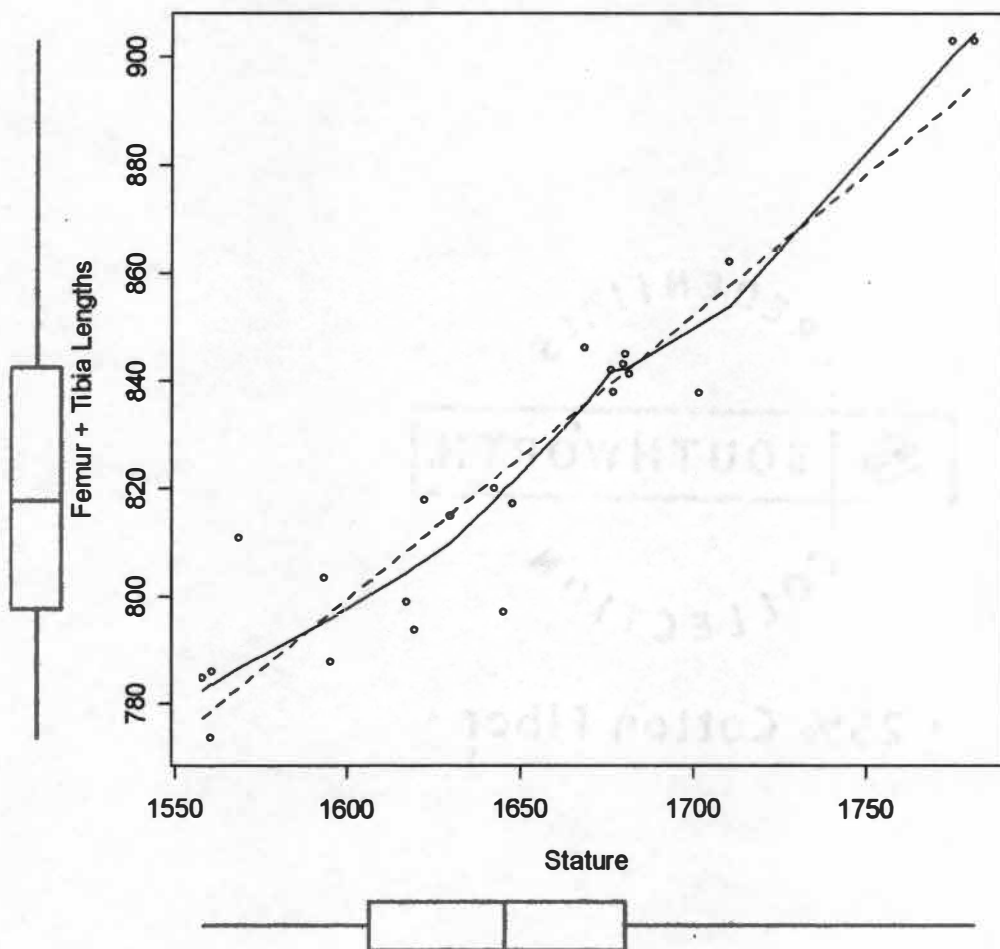


Figure 49. Males, Classic Calibration, Combined Femur and Tibia Lengths Regressed on Stature

Combined Femur and Tibia Lengths regressed on Stature:

$$\text{Stature} = ((\text{BFL} + \text{CMTL}) * 1.9044) + 76.8250 \pm 21.31848$$

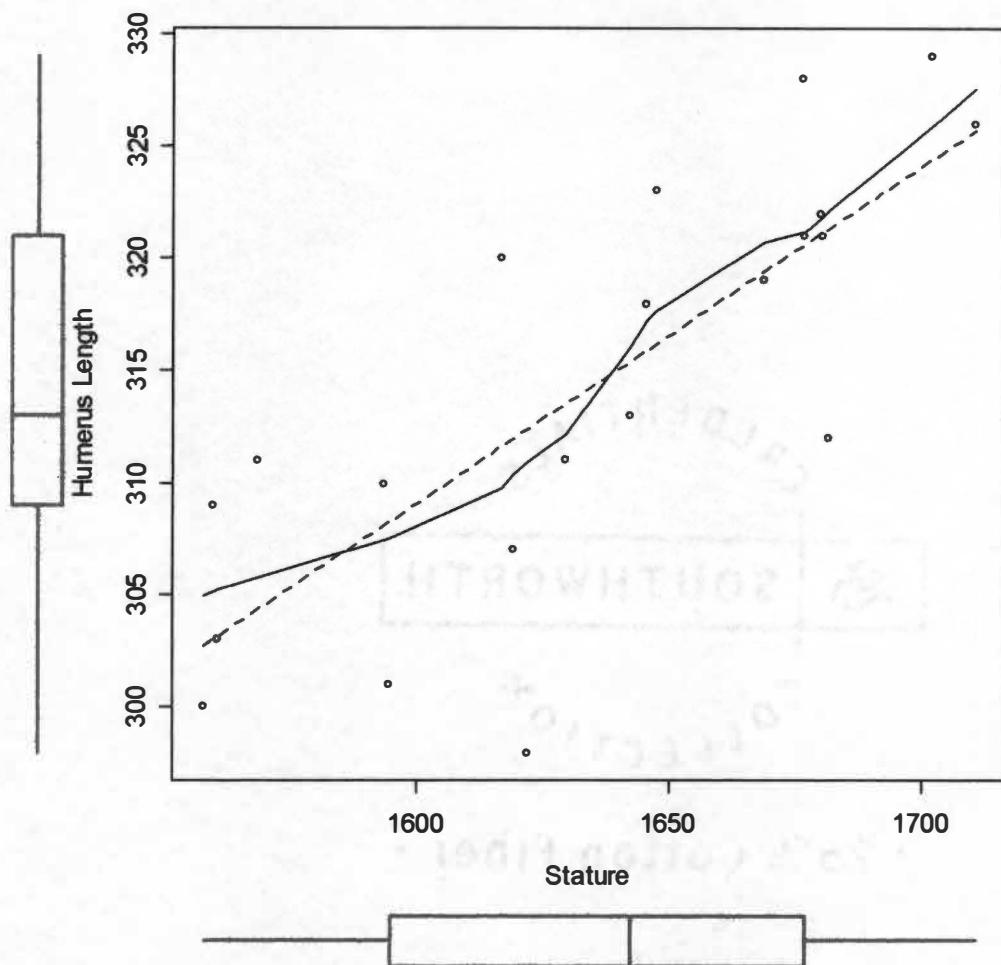


Figure 50. Males, Classic Calibration, Maximum Humerus Length Regressed on Stature

Humerus Length regressed on Stature:

$$\text{Stature} = ((\text{HML}) * 6.645) - 453.864 \pm 38.622$$

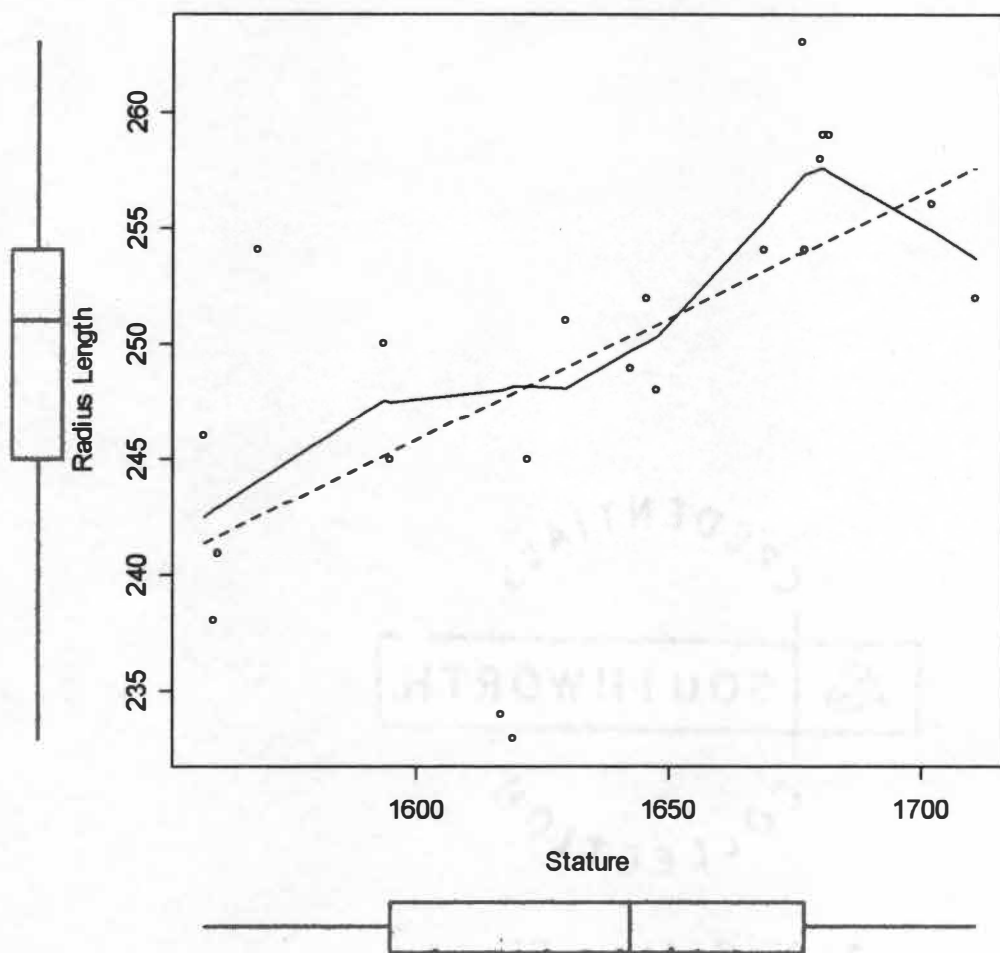


Figure 51. Males, Classic Calibration, Maximum Radius Length Regressed on Stature

Radius Length regressed on Stature:

$$\text{Stature} = ((\text{RML}) * 9.398) - 710.134 \pm 59.221$$

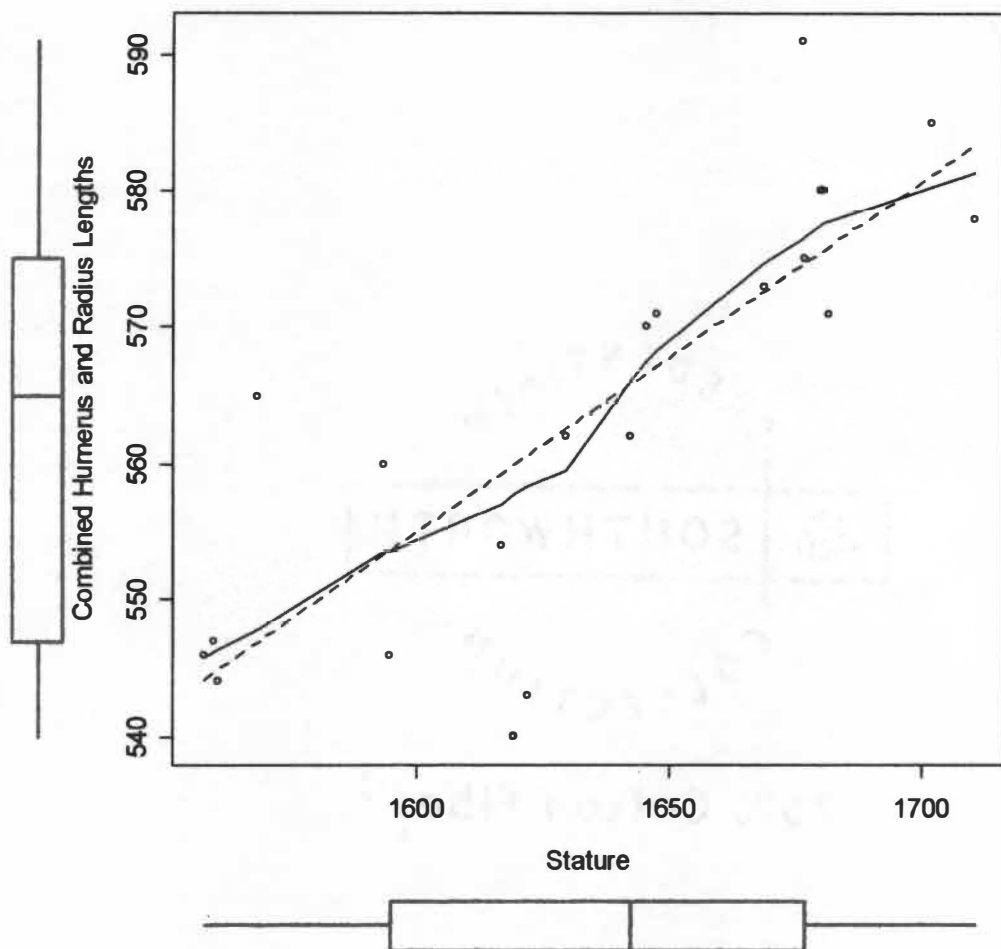


Figure 52. Males, Classic Calibration, Combined Humerus and Radius Lengths Regressed on Stature

Combined Humerus and Radius Lengths regressed on Stature:

$$\text{Stature} = ((\text{RML} + \text{HML}) * 3.893) - 560.003 \pm 34.813$$

Kathryn A. King was born in Charleston, West Virginia. She graduated with honors from Capital High School in 1996. That fall she entered the University of Kentucky as a chemistry major. Kathryn changed her major to anthropology in the spring of 1998. In May of 2000 she graduated cum laude with her Bachelor of Arts degree in anthropology.

Kathryn entered graduate school at the University of Tennessee in August of 2000. In December 2002 she was awarded the Master of Arts degree in anthropology.

Kathryn's main areas of interest include skeletal biology, forensic anthropology, and evolutionary theory as it applies to humans. She is particularly interested in finding new methods for estimating sex, ancestry, stature, and body mass from the human skeleton. Kathryn is a member of the American Association of Physical Anthropologists and Lambda Alpha, the national collegiate honors fraternity for anthropology.