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The Relationship of the Proximal Femur to the Femoral Length in Subadults From Different Populations

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The Relationship of the Proximal Femur to the Femoral Length in Subadults From Different Populations

Disciplines
Anthropology

THE RELATIONSHIP OF THE PROXIMAL FEMUR TO FEMORAL LENGTH IN
SUBADULTS FROM DIFFERENT POPULATIONS

By

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Abstract

The femur is an extremely variable bone in the human body that is nonetheless subject to heavy evolutionary and developmental pressures because of its key role in human locomotion. The size and shape of the proximal femur varies due to genetic, environmental, and behavioral factors, and some of this variation is already present in subadults (children). Hoppa and Gruspier (1996) suggested regression equations to estimate length from the proximal femur in fragmentary collections based on a group of remains from Ontario, however these equations may not be appropriate for all groups because of the great variability in shape in the proximal femur. I created new equations based on two Near Eastern collections, and found that although the femoral head and its relationship to length appears to be constant between populations, the mediolateral neck breadth of the femur may vary by population and population-specific equations may be necessary. However, although this variation may be due to real variation of the femoral neck length, it is impossible to distinguish whether the variation is due instead to interobserver unreliability of the measurement. In either case, these results suggest researchers should create their own regression equations for the groups they are studying.

Table of Contents

Background and Objectives	1
Introduction	2
Variation in the shape of the human femur	3
The femur in children and length estimation	7
Collections and Methods	10
Collections	11
<i>Bab edh-Dhra'</i>	11
<i>Hasanlu</i>	12
Measurements	13
Statistical analyses	13
Results	15
<i>Bab edh-Dhra'</i>	16
<i>Hasanlu</i>	16
Comparisons	17
Discussion and Conclusions	19
Femoral head diameter and length	20
Mediolateral neck breadth and length	21
Conclusions	23
References Cited	25
Tables and Figures	30
Table 1. Ontario ossuary femoral regression equations.	31
Figure 1. Map of Bab edh-Dhra'.	32
Figure 2. Map of Hasanlu.	33
Figure 3. Diagram of measurements taken on each subadult femur.	34
Table 2. Intraobserver error for Bab edh-Dhra' measurements.	35
Table 3. Comparison of measurements of right versus left femora from Bab edh-Dhra'.	36
Table 4. Regression equations based on the vertical head diameter (<i>P1</i>) of the Bab edh-Dhra' sample.	37
Figure 4. Regression equation based on the vertical head diameter (<i>P1</i>) of combined femora of the Bab edh-Dhra' sample.	38
Table 5. Regression equations based on the mediolateral neck breadth (<i>P2</i>) of the Bab edh-Dhra' sample	39
Figure 5. Regression equation based on the mediolateral neck breadth (<i>P2</i>) of combined femora of the Bab edh-Dhra' sample.	40
Table 6. Interobserver error for Hasanlu measurements.	41

Table 7. Comparison of measurements of right versus left femora from Hasanlu.	42
Table 8. Regression equations based on the vertical head diameter (<i>P1</i>) of the Hasanlu sample.	43
Figure 6. Regression equation based on the vertical head diameter (<i>P1</i>) of combined femora of the Hasanlu sample.	44
Table 9. Regression equations based on the mediolateral neck breadth (<i>P2</i>) of the Hasanlu sample	45
Figure 7. Regression equations based on the mediolateral neck breadth (<i>P2</i>) of combined femora of the Hasanlu sample	46
Figure 8. Regression equations for vertical head diameter (<i>P1</i>).	47
Figure 9. Regression equations for the mediolateral neck breadth (<i>P2</i>).	48
Table 10. Differences between real femoral lengths from Bab edh-Dhra' and those estimated from Hoppa and Gruspier (1996) and Hasanlu regression equations.	49
Figure 10. Bab edh-Dhra' observed lengths plotted against the Hoppa and Gruspier (1996) and Hasanlu regression equations for vertical head diameter (<i>P1</i>).	50
Figure 11. Bab edh-Dhra' observed lengths plotted against the Hoppa and Gruspier (1996) and Hasanlu regression equations for mediolateral neck breadth (<i>P2</i>).	51
Table 11. Differences between real femoral lengths from Hasanlu and those estimated from Hoppa and Gruspier (1996) and Bab edh-Dhra'.	52
Figure 12. Hasanlu observed lengths plotted against the Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for vertical head diameter (<i>P1</i>).	53
Figure 13. Hasanlu observed lengths plotted against the Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for mediolateral neck breadth (<i>P2</i>).	54
Figure 14. Hasanlu citadel observed lengths plotted against Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for mediolateral neck breadth (<i>P2</i>) only.	55
Table 12. Equations based on combined Hasanlu and Bab edh-Dhra' samples.	56
Figure 15. Regression equations for the femoral head diameter (<i>P1</i>), based on combined samples.	57
Figure 16. Regression equations for the mediolateral neck breadth (<i>P2</i>), based on combined samples.	58
Table 13. Comparison of R within each sample.	59
Data	60

Background and Objectives

Introduction

The human femur, the upper bone of the leg, is a robust part of the skeleton and has evolved as a weight-bearing structure in humans (Garden 1961). Humans are obligate bipeds, meaning we locomote exclusively on our two rear limbs. Because of this, the femur is responsible for supporting the weight of an individual, not only at rest while standing, but also through a myriad of activities such as walking, climbing, and carrying objects, and because of these varied functions it has evolved its characteristic shape (Garden 1961).

The proximal, or upper, femur in humans consists of a spherical head covered with a thick cartilage, a neck, and the greater and lesser trochanters (Hoaglund and Low 1980; Figure 3, p. 34). The head forms a joint with the pelvis, and this articulation requires a certain amount of curvature, or anteversion, in the femur (Hoaglund and Low 1980). As a load-bearing and locomotor bone, the femur is subject to multiple forces--the upper body exerts a compressive force on the head and on the rest of the proximal femur, as does the musculature, resulting in forces of about four times body weight (Pauwels 1976). These forces act on the entire femoral head equally, but, because of the differences in angle between the neck and the forces, they bend the femoral neck, which behaves like a lever arm (Pauwels 1976). In addition, this region is subject to shearing forces distributed equally at all points (Pauwels 1976).

In fetuses and young infants, the femur is mostly straight and undefined, but the ossification centers and epiphyseal surfaces for the femoral head and the trochanters begin appearing by around three years of age (Scheuer and Black 2000). The epiphyses for the head and trochanters generally fuse between the ages of 14 and 19, but can remain unfused into the 20s (Bass 1995).

These general characteristics apply to all healthy human femora. However, bone is a dynamic tissue that alters its shape and composition in response to environmental pressures, so there is great variation in femoral morphology even within the constraints of its evolved shape (review in Ruff *et al.* 2006).

Variation in the shape of the human femur

Multiple sources of evidence suggest that the basic, underlying shape of bones, including the femur, derives primarily from “systematic expression of positional information”—that is, the overall shape is genetically determined, and any effects on the shape from use and adaptation during life are purely localized and probably limited during development (review in Lovejoy *et al.* 2002). In accordance with this evidence, it has been shown that some fundamental aspects of femoral morphology are present before birth: for example, the shape of the distal epiphysis is already significantly different from that of other apes among human fetuses (Tardieu 1999). It displays the shape that is characteristic of adult humans, which is associated with the angulation of the bipedal femur (Tardieu 1999). However, the angle itself seems to appear only in response to usage—the daily stresses of bipedal locomotion lead to the characteristic femoral bicondylar angle found in humans (Shefelbine *et al.* 2002). This angle forms as the bone responds to different loads on its many sides with differential growth (Shefelbine *et al.* 2002), and reaches adult values by about seven years of age (Tardieu 1999). In children who cannot walk, the angle never develops (Tardieu 1999). In order to reduce stress from different sorts of forces, the cross-sectional area of bone must increase, and there is evidence that the internal architecture changes as it adjusts to different force distributions (Pauwels 1976). Abnormalities in the underlying structure will result in changes in external shape to deal with the abnormal distribution of forces

(Pauwels 1976). Other aspects of femoral form also develop over time, though they may be epigenetically or genetically determined. For example, the shape of the femoral head epiphysis changes throughout childhood and adolescence (Scheuer and Black 2000).

Evolutionary forces play a role in femoral morphology through these genetic and developmental mechanisms, and there is evidence for subtle changes in shape across closely related species, associated with ecological factors that would act as selective pressures. For example, different bovine species, who have similar locomotor patterns, show different shapes of the proximal femur and femoral shaft according to the specific type of habitat in which they live (Kappelman 1988). Bovine species who live primarily in the forest show femoral head morphology that allows greater flexibility in movement, while those who live in open habitats show femoral head morphology that limits certain types of movement (Kappelman 1988). These locomotor adaptations probably allow increased access to food and improved avoidance of predators, respectively (Kappelman 1988). The evidence for modern human femoral morphology and variation is also ample in the evolutionary record. Early hominin fossils depict proximal femora that are similar to those of modern humans and were well adapted to bipedalism (e.g. Lovejoy *et al.* 2002). However, within that general adaptation, cold-adapted humans have relatively larger femoral heads and ends, thicker shafts, and low angles when compared to warm-adapted humans (Weaver 2003). These relationships hold not only when comparing Neanderthals to modern humans, but for modern human groups who have historically lived in the arctic (Weaver 2003).

Ethnic or population variation in femoral shape could be due to multiple factors, not just those selected for by particular ecological contexts. There appears to be ethnic variation in degree

of femoral anteversion (Eckhoff *et al.* 1994) and femoral curvature, possibly due to genetically-based differences in length, width, and density of bone (Walensky 1965). Even within populations there is a great deal of variation in these measures, with anteversion varying between -2° and 36° degrees among Caucasians, and between -4° and 28° among Hong Kong Chinese, and with males and females showing different means (Hoaglund and Low 1980). There are significant differences in femoral neck length between different ethnicities when adjusted for height (Chin *et al.* 1997) and there are also be variations in distal femoral shape among ethnic groups, with Caucasian women having generally larger distal femora than Japanese women (Urabe *et al.* 2008). Both genetic and other factors, such as nutrition and lifestyle, may contribute to these differences (Chin *et al.* 1997). However, monozygotic and dizygotic twin studies suggest that there is a significant genetic component to many aspects of proximal femur morphology (Slemenda *et al.* 1996). Further, males and females tend to have different femoral shapes and male femoral heads and diaphyses are, on average, larger than female ones (Noble *et al.* 1995).

'Lifestyle', which may affect femoral shape, encompasses a great deal of behavioral and environmental factors. It has been shown, for example, that activity levels alter bone density and shape. These effects are especially evident with activities prior to full skeletal maturation. In one experiment, mice that engaged in exercise before skeletal maturation was complete had greater bone area and greater bone dimensions in the femoral head than a control group (Plochocki *et al.* 2006). Similarly, miniature Yucatan swine showed an increase in bone thickness in the shaft with regular exercise (Woo *et al.* 1981). Such results may occur simply because the control group fails to reach a minimal level of activity necessary for proper development (Lovejoy *et al.* 2002), but the importance of behavior to the development of morphology remains. In general, similar, but

less extreme, activity-related changes take place in adult bones (e.g. Lieberman *et al.* 2001). Experimental results indicate that adult sheep moving on concrete have increased bone thickness at the knee joint when compared to sheep on a wood chip or pasture surface (Radin *et al.* 1982). Similarly, in archaeological human remains from the Arikara, for example, it has been found that female femoral morphology and asymmetry changed along with the increase in intensity of their labor as they shifted towards producing surplus crops (Wescott and Cunningham 2006).

In addition to these broad genetic and behavioral factors, the internal structure and shape of the human proximal femur changes differently between the sexes with age (e.g. Noble *et al.* 1995, Cui *et al.* 2008). In both men and women, the femoral shaft becomes wider with age, but in women this occurs along with a decrease in cortical thickness that leads to changes in the shape of the internal structure of the femur and its medullary canal (Noble *et al.* 1995). The angle of the femoral neck changes, going from 123.9° to 126.9° on average, and, in women, there is a decrease in the height of the femoral head relative to the lesser trochanter (Noble *et al.* 1995). Meanwhile, the internal volume of bone decreases with age as does the structure of this internal bone, and the change is significant in the neck and trochanteric regions (Cui *et al.* 2008).

However, the articular surfaces of long bones are less subject to external changes in shape because the nature of the articulation would require a change in multiple structures (Pauwels 1976). Articular surfaces have been shown experimentally to be less variable than the diaphysis when subjected to different mechanical loads (Lieberman *et al.* 2001). Although there are differences in the articular surface area of the proximal femur between exercise and control groups of sheep in the Lieberman *et al.* (2001) paper, these are not statistically significant. The femoral head also shows a strong correlation to body mass across species, although in humans it

is relatively larger than in other hominoids (Ruff 1988). This increase in relative size is probably due to a need for strength and stability in bipedal locomotion and extends to early fossil hominids (Ruff 1988). The magnitude of stress from compressive forces from the body will depend on the area on which those forces are distributed (Pauwels 1976), so not only do humans need a relatively larger femoral head (for the relatively greater amount of weight supported on the femur alone in a bipedal stance) but larger humans must have larger femoral heads to support the added weight (e.g. van Gerven 1972). The size of the femoral head does not change with age or activity levels (Ruff 1988, Noble *et al.* 1995) and is maintained despite changes in diaphyseal measurements due to changes in activity (Pauwels 1976).

The femur in children and length estimation

It has been shown that some aspects of adult shape of the femur are established by approximately five years of age, when a mature gait is finally attained (Wescott 2006). Wescott (2006) found that Native American subadults (children) could be differentiated from American black or white subadults based on subtrochanteric diameters and the shape of the diaphysis, and that there were no changes in the differences between the groups after that age. The mediolateral diameter also changed more rapidly in Native American children when compared to length (Wescott 2006). Similarly, the epiphyseal surface where the femoral head will fuse onto the diaphysis appears around age two, as does the femoral neck, probably due to the pressures of walking (Scheuer and Black 2000).

There is some evidence that the relationships of the femoral head diameter and of the femoral neck breadth to femoral length vary by population (Hoppa and Gruspier 1996). However, these comparisons are incomplete. Hoppa and Gruspier (1996) created linear regression equations

(Table 1, p. 31) for subadult femora from two Ontario ossuaries, but only compared one of these equations to a small sample from Italy. This comparison revealed statistically significant differences between the estimated lengths and the true lengths, and Hoppa and Gruspier (1996) suggest this is due to poor health in the Italian group leading to retarded growth. However, femoral length may be more stable than other long bone lengths in the face of stress and malnutrition. There is little between- or within-group variation in femoral length by age among Arikara of different periods, despite significant variation in the lengths of other bones in the body, for example (Jantz and Owsley 1984), and secular changes in limb bone length due to improved conditions seem to occur primarily in distal elements of the limbs--that is, in the leg, the tibia and fibula and not the femur (Jantz and Jantz 1999). Further, it seems unlikely that growth retardation due to malnutrition or ill health would affect only the length of long bones and not their overall size, development, or articular surfaces.

An earlier, unpublished study conducted by Hoppa (referenced in Hoppa and Gruspier 1996), also suggested that the equations derived from one ethnic group were not applicable to other groups. It may be that these results were due to real ethnic differences, genetic or environmental, though they may be due to other factors, such as the reliability of measurement. A great deal of experimental and archaeological evidence suggests that these differences could be real, however.

To determine the applicability of such regression equations to different populations and to determine whether relationships between the proximal femur and femoral size in subadults vary among populations, I will use the Ontario equation as well as data from two other collections to test the hypothesis that there are no differences between actual lengths and estimated lengths,

derived from equations determined for different populations. If there are no differences between actual and predicted lengths, it means that the proximal femur bears the same or similar relationship to femoral length across populations and, in turn, that the equations are broadly applicable. This would suggest that many of the apparent differences in femoral morphology appear in adolescence or adulthood. If there are differences, however, it would lend further support to the hypothesis that genetic, environmental, and ethnic variation in femoral shape appears early in life.

Collections and Methods



Collections

Subadults were assessed by me or other authors based on a combination of indices of dental or skeletal maturation. Smay (2005) included anyone under 17 years of age, based on dental maturation, as a subadult. Only femora whose epiphyses were unfused were measured, and, because specific ages are not important to this study, they were not recorded separately.

Bab edh-Dhra'. This collection comes from shaft tombs at Bab edh-Dhra', Jordan (Figure 1), dated to the Early Bronze I (EB I, 3300-3000 BCE) period, and consists of a minimum of 339 subadult individuals, based on all skeletal elements (Ortner and Frohlich 2008). These shaft tombs are found in a large cemetery spanning several centuries and probably represent secondary burial sites--that is, the bodies were initially kept elsewhere and then transferred into these tombs (Ortner and Frohlich 2008). The collection is well-preserved and well-excavated, and most damage to the skeletal material probably occurred due to ceiling collapse in the tombs or loss and breakage when bones were moved between their primary and secondary burial places (Ortner and Frohlich 2008). This site is located on the Dead Sea Plain and would have had access to fresh water and arable land during the period of occupation (Rast and Schaub 2003), in which the land would have been a humid wooded savannah (Harlan 2003). The evidence seems to suggest that the EBI tombs were built by nomadic pastoralists during their seasonal occupation of the area, people who later settled the site permanently (Rast and Schaub 2003). Evidence from the later settlement suggests they cultivated primarily sheep, goats (Rast and Schaub 2003), various fruits, wheat, and barley (Harlan 2003). These people seem to be closely related to other groups from the Near East (Ortner and Frohlich 2008). However, it also seems likely that the population, especially the infants, were exposed to infectious and parasitic diseases and malnutrition (Ortner

and Frohlich 2008). From this collection, a total of 35 individuals were useful for this study. This collection is housed at the Smithsonian Museum of Natural History.

Hasanlu. This collection comes from the Solduz-Ushnu Valley in northern Iran (Figure 2), dates to between 1400 and 800 BCE, and represents a mixture of cemetery skeletons and skeletons of individuals killed in the citadel during an enemy attack (Smay 2005). The site is in a dry, mountainous region (Smay 2005). Archaeological evidence indicates that the inhabitants at the site were a sedentary agricultural group, and that barley was a staple crop, along with lentils, chickpeas, grapes, pears, apples, pistachios, and almonds (in Smay 2005). Hasanlu has only been partially excavated (Smay 2005), and the sample consists of a minimum of 89 subadult individuals based on all skeletal elements. From this collection, a total of 20 individuals were useful for this study. This collection is housed at the University of Pennsylvania Museum of Archaeology and Anthropology. This collection has samples both from a cemetery and a citadel, whose inhabitants were killed in an attack and who appear generally healthier than the individuals from the cemetery (Smay 2005). This should allow some testing of Hoppa and Gruspier's (1996) suggestion that differences in length estimates were due to poor health in the non-Ontario groups.

The collection described in the original Hoppa and Gruspier (1996) paper comes from two Ontario ossuaries, the Fairty and Kleinburg ossuaries, near modern-day Toronto and dating to the Woodland period between 1300 and 1350 CE and 1580 and 1600 CE. These ossuaries are also secondary burial places, belonging to sedentary maize-based agricultural societies (Katzenberg 1992). There is significant evidence for infectious diseases among these samples, both in adults and subadults (Katzenberg 1992).

Measurements

All measurements were taken twice by me alone for the Bab edh-Dhra' EB I collection. The Hasanlu collection was measured by both Cassandra M. Turcotte and myself, once each. The following measurements were taken using an analog or digital caliper, as available, that is accurate to 0.02 mm, following Hoppa and Gruspier (1996).

- *Vertical head diameter (P1)* - the sagittal diameter of the epiphyseal surface, analogous to the femoral head diameter on adult femora (Hoppa and Gruspier 1996). (Figure 3.A)
- *Mediolateral neck breadth (P2)* - the maximum breadth of the femoral neck from the most lateral edge of the femoral head epiphyseal surface to the most lateral edge of the greater trochanter, taken with the caliper parallel to the shaft (Hoppa and Gruspier 1996). (Figure 3.B)

The following measurement was taken in millimeters using a standard osteometric board.

- *Diaphyseal length (ODL)* - diaphyseal length measured according to the standards for immature remains in Buikstra and Ubelaker (1994).

Statistical analyses

Inter- and intra-observer error was determined, when possible, using two-tailed paired *t*-tests. These were determined for left, right, and combined measurements, where combined included both left and right for a given individual, since the purpose of these tests was to determine reliability. All measurements of the right and left sides were tested for differences between sides using two-tailed *t*-tests for unpaired samples of equal variance. The average measurement for each measurement of each bone was used for the rest of the analyses.

Linear regression equations for length (y) were determined, using vertical head diameter and mediolateral neck breadth as independent variables (x) for left, right, and combined femoral measurements; linear regressions were found previously to provide a fit as good as a non-linear regression (Hoppa and Gruspier 1996). When both femora from an individual were present, the left was used in the combined equation. When a measurement was missing from the left femur but was available for the right femur of an individual, the right measurement was used for that point only. Only femora where both length and at least one additional measurement could be obtained were used. The Hoppa and Gruspier (1996) equations were used to estimate lengths of Bab edh-Dhra' and Hasanlu femora of known length from $P1$ and $P2$, and these estimates were compared to the known lengths using two-tailed paired t -tests. This same procedure was followed with the combined equations to estimate Hasanlu lengths from the *Bab edh-Dhra'* equation and vice versa. The Hasanlu citadel remains were evaluated both as part of the complete Hasanlu sample and separately.

A result was considered statistically significant when p was below 0.05 (95%).

Results

Bab edh-Dhra'

This collection was measured only by me. Intraobserver error is presented in Table 2 (p. 35). The only significant intraobserver differences occurred when the mediolateral neck breadth ($P2$) of the right femora was analysed. In the combined and right-only samples, this measurement was significantly different between observations ($p < 0.05$).

For the left side, 7 femora could be measured for $P1$ and length, and 20 could be measured for the $P2$ and length. For the right side, 9 femora could be measured for $P1$ and length, and 27 could be measured for $P2$ and length. For the combined sample, 13 femora could be measured for both $P1$ and length, and 35 could be measured for both $P2$ and length. Given the MNI of 339 subadults, this is approximately 3.83% of the cemetery sample for $P1$ and 10.32% percent for $P2$. There was no significant difference between measurements of left and right for length (Table 3, p. 36). Regression equations were derived from the femoral head diameter (Table 4, p. 37; Figure 4, p. 38) and from the mediolateral neck breadth (Table 5, p. 39; Figure 5, p. 40).

Hasanlu

This collection was measure by C. M. Turcotte and myself. Interobserver error is presented in Table 6 (p. 41). There were no significant differences between observers for any measure for left, right, or combined samples.

For the left side, 12 femora could be measured for $P1$ and length, and 13 could be measured for $P2$ and length. For the right side, 12 femora could be measured for $P1$ and length, and 14 could be measured for $P2$ and length. For the combined sample, 17 femora could be measured for both $P1$ and length, and 20 could be measured for both $P2$ and length. Given the MNI of 89 subadults, this is approximately 19.1% of the sample for $P1$ and 22.47% of the sample

for *P2*. There was no significant difference in the right versus the left femora (Table 7, p. 42). Regression equations were derived from the femoral head diameter (Table 8, p. 43; Figure 6, p. 44) and mediolateral neck breadth (Table 9, p. 45; Figure 7, p. 46).

Comparisons

All regression equations and data points are shown on Figure 8 (p. 47) for the vertical head diameter (*P1*), and on Figure 9 (p. 48) for the mediolateral neck breadth (*P2*).

For the Bab edh-Dhra' collection, the Hoppa and Gruspier (1996) regression equations provided length estimates from *P1* that were not significantly different ($p = 0.5513$), but estimates from *P2* that were significantly different ($p < 0.0001$). The Hasanlu derived regression equations similarly provided length estimates from *P1* that were not significantly different ($p = 0.2251$) and estimates from *P2* that were significantly different ($p = 0.0064$). (Table 10, p. 49; and Figures 10, p. 50, and 11, p. 51).

For the entire Hasanlu collection, the Hoppa and Gruspier (1996) regression equations provided length estimates from *P1* that were not significantly different ($p = 0.3536$), but estimates for *P2* that were significantly different ($p < 0.0001$). Similarly, the Bab edh-Dhra' derived regression equations gave length estimates from *P1* that were not significantly different ($p = 0.0661$) and estimates for *P2* that were significantly different ($p = 0.0495$). (Table 11, p. 52; and Figures 12, p. 53, and 13, p. 54). When only the Hasanlu citadel was compared, the results held for the Hoppa and Gruspier (1996) equations ($p = 0.8933$ for *P1* and $p < 0.0001$ for *P2*), but not for the Bab edh-Dhra' regression equations, where neither estimates were significantly different ($p = 0.2887$ for *P1* and $p = 0.1998$ for *P2*). (Table 11, p. 52; and Figure 14, p. 55).

The two samples from the Near East were combined and used to make additional regression equations (Table 12, p. 56; Figures 15, p. 57 and 16, p. 58). These were significantly different from the Hoppa and Gruspier (1996) equations ($p = 0.0003$ for $P1$ and $p < 0.0001$ for $P2$).

There is no significant difference between the correlations of $P1$ and $P2$ sample specific equations ($p = 0.0908$ for Hasanlu and $p = 0.1229$ for Bab edh-Dhra', Table 13, p. 59). However, $P2$ is significantly more correlated in the combined sample ($p = 0.0277$).

Discussion and Conclusions

Femoral head diameter and length

The Ontario ossuary equations (Hoppa and Gruspier 1996) for femoral head diameter predicted lengths that were not significantly different from the actual lengths, as did the Bab edh-Dhra' and Hasanlu equations. This result is consistent with previous research that concluded that the femoral head, being an articular surface, scales with body size and is not affected by the environment (Ruff 1988). When plotted against each other (Figure 8, p. 47), the equations for the head diameter intersect, and the data points are distributed around all three equations. It seems possible then, that, with a sufficient sample size, all groups would give very similar regression equations—Hoppa and Gruspier (1996) used a sample size of 205 to construct this regression equation, while the samples used here were only of 13 for Bab edh-Dhra' and 17 for *Hasanlu*. The estimated lengths from the equation based on both samples (Figure 15, p. 57) were significantly different from those estimated by Hoppa and Gruspier (1996) though there were no differences between the lengths estimated by the Hoppa and Gruspier (1996) equations and the observed lengths ($p = 0.2589$ for the combined samples), and this may be because the distribution of the combined samples is concentrated towards the lower size range so that, when it is pooled, it is skewed (Figure 15, p. 57).

Interestingly, Hoppa and Gruspier (1996) reported significant differences when they compared estimates from the Ontario equation for head diameter with observed lengths of a medieval Italian sample (*Cosa*, $p = 0.008$, Hoppa and Gruspier 1996: Table 5). It may be, as they suggested (Hoppa and Gruspier 1996), that when differences between estimated and observed lengths are significant, it is indicative of a pathology which, in this case, would alter the relationship of the femoral head to body size. However, it may also be that the sample

distributions were different, weighing the statistical analyses in one particular direction that may not be representative.

Mediolateral neck breadth and length

The results for the mediolateral neck breadth were mixed. The Hoppa and Gruspier (1996) Ontario equations estimated lengths that were significantly different in all cases, including when the Near Eastern samples were combined ($p < 0.0001$). The Hasanlu equation likewise estimated significantly different lengths for Bab edh-Dhra' femora. While these results for mediolateral neck breadth would remain significant at $p = 0.01$ and, for the Hoppa and Gruspier (1996) equation, even at $p = 0.001$, the Bab edh-Dhra' equation estimates for Hasanlu were close to being insignificant even at $p = 0.05$ ($p = 0.0495$) and were insignificant when only Hasanlu's citadel data was used.

These results for the mediolateral neck breadth could be explained in many ways. The mediolateral neck breadth is not a measure of an articular surface and is a function of the shape of the femoral shaft (Buikstra and Ubelaker 1994), it seems to experience great changes in size and shape due to use (Pauwels 1976), and it is formed in part by the femoral neck, which seems to be subject to a great deal of variation between populations (e.g. Chin *et al.* 1997). The femoral neck length affects the the magnitude of stress experienced by the bone, and is associated to factors such as femoral neck angles and torsion (e.g. van Gerven 1972, Pauwels 1976), as well as pelvic size (e.g. Van Gerven 1972). For these reasons, we could expect differences between the groups. Because the two Near Eastern groups shared similar environments and likely similar diets, came from similar time periods, and shared a more recent and closer genetic relationship than with the Ontario groups, they may have more similar, but not necessarily identical, femoral shapes, while

the Ontario groups, who differed in nutrition, development, and potentially body size and shape, have differently shaped femurs, leading to the inappropriateness of the Ontario regressions for the Near Eastern groups. Evidence for the size and shape similarity among the Near Eastern groups comes from other sources--the heights for the Bab edh-Dhra' adults were similar to those from other groups in the region, with a male average of 166 cm and a female average of 156 cm (compared to 165-171 cm for males and 153-162 cm for females in the region) (cited in Ortner and Frohlich 2008). However, other Native American groups have average heights that fall within these ranges (e.g. 154.1 cm average for prehistoric Ohio females and 164.3 cm for males, Sciulli *et al.* 1990), and there may be differences in body proportions rather than in overall size. It may also be that the environments were sufficiently different that some selection took place on the shape of the femur in the populations of each region, leading to similar underlying shapes in individuals from regions with similar environmental situations (as in bovids in Kappelman 1988, and cold adapted humans in Weaver 2003). It would be useful to compare these shapes at multiple points and three-dimensionally and to be able to incorporate the pelvis into these analyses.

The inconsistencies between Hasanlu and Bab edh-Dhra' could in turn be due to differences in sample size and size distributions. When plotted with each other (Figure 9, p. 48), it is clear that the distributions of the observed sizes are different—Hasanlu has larger femora, and has fewer smaller femora than Bab edh-Dhra'. The two equations are very close to each other and are almost parallel, which may indicate that with sufficient and more evenly distributed samples, the two equations would be the same. When combined (Figure 16, p. 58) into one equation, the *R* value, representing the correlation, remains high ($R = 0.9902$, or more than

99.0%). In this case, it would be useful to have evenly distributed samples and compare regression lines from those.

However, another possibility to explain the inconsistencies with the mediolateral neck breadth is that this is a measure that is difficult to reproduce. This measurement is not described in Bass (1995) or Buikstra and Ubelaker (1994), two of the major osteological manuals, and the description in Hoppa and Gruspier (1996) does not include a graphical representation of the measurement. The mediolateral neck breadth has no clear-cut markers, unlike the femoral head diameter, which is clearly delimited by the boundaries of the epiphyseal surface for the head or by the femoral head itself (Figure 3). These factors could make it difficult for different researchers to replicate the measurement. There were some significant differences between trials when I measured the mediolateral neck breadth for Bab edh-Dhra', and Hoppa and Gruspier (1996) also reported significant interobserver differences ($p < 0.001$). The fact that the Bab edh-Dhra' and Hasanlu measurements, both taken by the same person, give such similar regression equations (Figure 9, p. 48) could suggest that, in fact, the apparent differences between the Ontario regressions and the Near Eastern ones are due to differences between the observers. To test this, it would be necessary for the same author to measure many more groups of variable origins.

Conclusions

In general, these results indicate that the different parts of the femur behave quite differently in respect to femoral length. The femoral head seems to maintain its relationship across groups, and a generalized equation may be appropriate, as is used for body size estimation in other species (e.g. Niskanen and Junno 2009). Meanwhile, the mediolateral neck breadth

shows considerable variation. This may be due to the difficulty in reproducing the measurement itself, and researchers may need to make their own regression equations if only to control for differences between observers. The more interesting result would be if this variation was due to actual variation in the femora, and not simply to observer differences. This would indicate differences in femoral shape in subadults that are important both archaeologically and biologically, in terms of their implications about development, health, environment, and genetics, and in terms of how we study all these factors. It may be necessary to construct equations for each particular group being studied, or at least to have equations that are appropriate for similar, regional groups with shared genetic and environmental backgrounds, such as Hasanlu and Bab edh-Dhra'. However, in either case, researchers should show caution in the use of such regression equations, and should attempt to create their own for each population.

In the future, it would be useful to quantify three-dimensional shape differences in the femora of these populations, as this would better illuminate where the differences lie. It would also be useful to expand such comparisons to multiple additional populations, if only to determine whether differences are due to observer errors or to real variation among human groups.

These sorts of studies are useful for archaeological and forensic applications, where length estimation may be necessary in order to understand paleodemographic or paleopathological variables, or to identify individuals, respectively. This is especially useful when length estimates must be used for age, stature, or health estimation (e.g. by comparing long bone length to dentally determined ages). If appropriate regression equations are not used in such endeavors, then the results will be wrong.

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Tables and Figures

Key to tables and figures:

- R^2 represents the amount of variation in y explained by x .
- F is a measure for the statistical significance of the model, when present for regression equations. In other cases, F is a measure of relative variance used to determine the t -test.
- s_e represents the standard error, a measure of goodness of fit.
- $d.f.$ stands for degrees of freedom.
- β represents the slope in a regression equation.
- α represents the constant in a regression equation.
- p is considered significant at $p < 0.05$ in all cases.
- $P1$ stands for femoral head diameter
- $P2$ stands for mediolateral neck breadth
- ODL stands for observed diaphyseal length

Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Vertical head diameter (<i>P1</i>)	205	0.9749	17.0009	7632.09	< 0.0001	11.0789	-39.5668
Mediolateral neck breadth (<i>P2</i>)	74	0.9782	12.5551	3281.16	< 0.0001	4.9358	-70.2761

Table 1. Ontario ossuary femoral regression equations. Length is the dependent variable (*y*) and *P1* or *P2* is the independent variable (*x*). Modified from Hoppa and Gruspier (1996: Table 4).

Figure 1. Map of Bab edh-Dhra', Jordan, at 31° 15' 15"N 35° 32' 50"E. Represented by red dot.

Map (c) 2010 Google, AND, Mapa GISrael, ORION-ME.

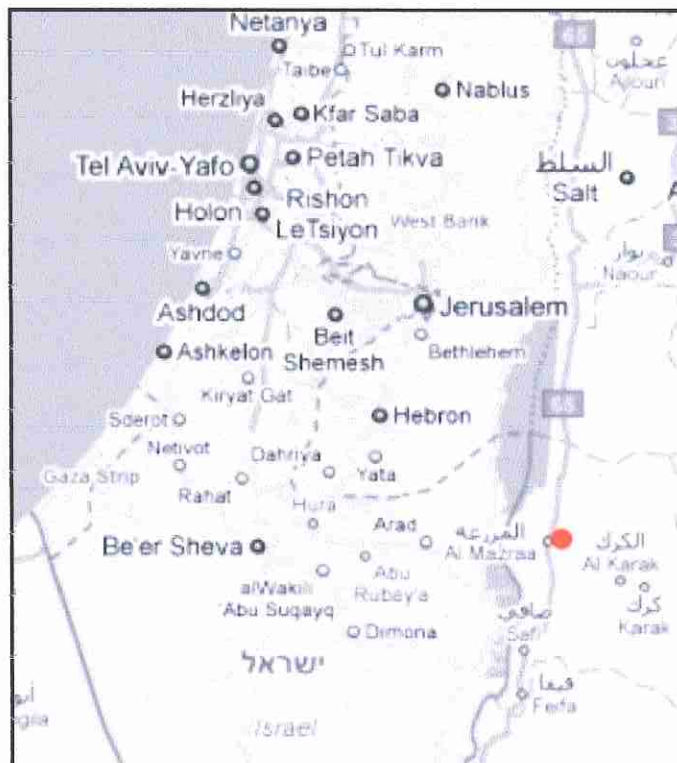
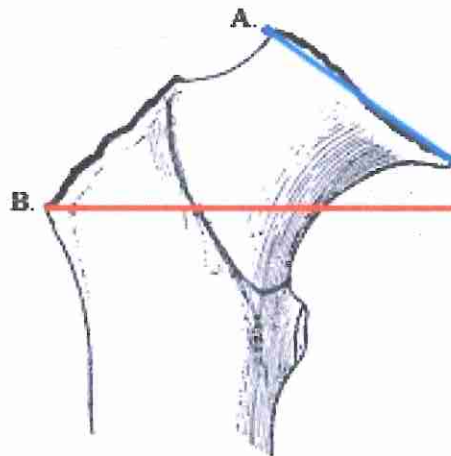
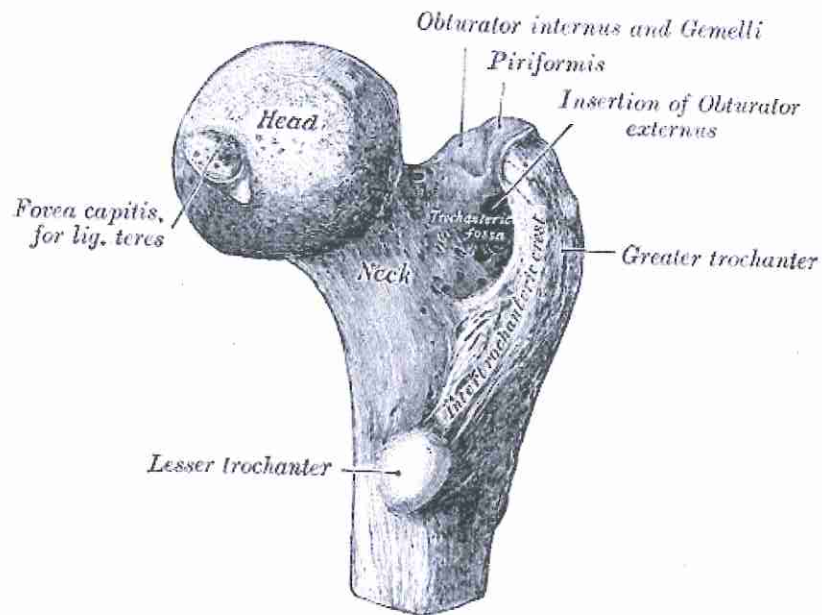


Figure 2. Map of Hasanlu, Iran, at 37° 00'17.39"N 45°27'32"E. Represented by red dot. Map (c) 2010 Europa Technologies, Google, AND, Basarsoft, Geocentre Consulting, LeadDog Consulting, Mapa GISrael, ORION-ME, Tele-Atlas.



Figure 3. Diagram of femur (Gray 1918, fig. 243) and of measurements taken on each subadult femur (based on Hoppa and Gruspier 1996). **A.** (blue line) Femoral head diameter, *P1*. **B.** (red horizontal line) Mediolateral neck breadth, *P2*. Epiphyses are shown faded. Image modified from Gray (1918, fig. 253).



Measurement	Side	<i>p</i>	<i>t</i> -value	d.f.
ODL	Left	0.4108	0.8393	21
	Right	0.9245	0.0956	29
	Combined	0.6736	0.4237	51
P1	Left	0.3130	1.0688	9
	Right	0.8142	0.2395	14
	Combined	0.8727	0.1620	24
P2	Left	0.7895	0.2697	26
	Right	0.0146	2.5685	35
	Combined	0.0363	2.1404	62

Table 2. Intraobserver error for Bab edh-Dhra' proximal femur measurements.

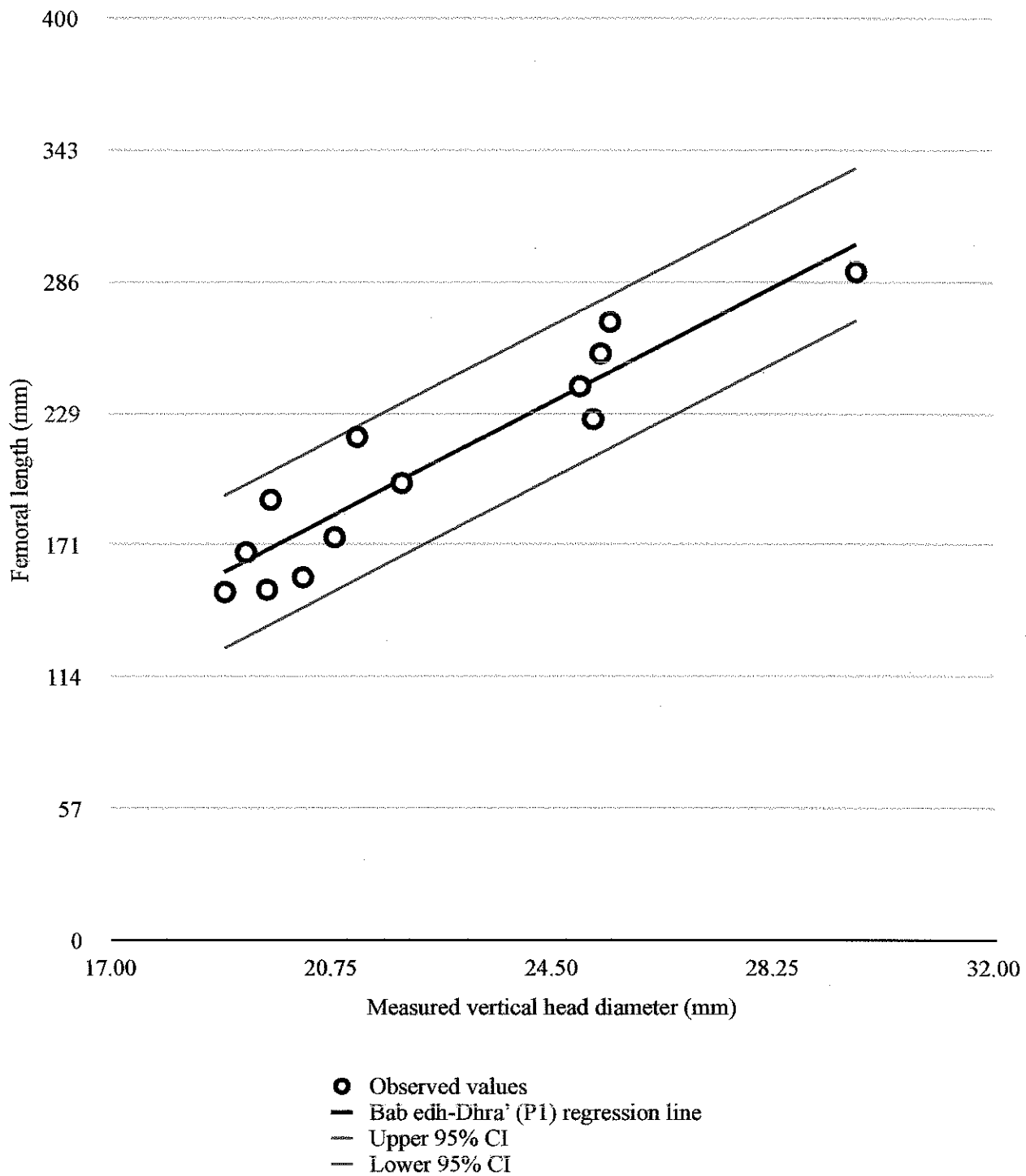
Measurement	F	<i>p</i>(F)	<i>p</i>	<i>t</i>-value	d.f.
ODL	1.2459	0.2967	0.2348	1.2042	45
P1	1.0636	0.4542	0.7792	0.2858	14
P2	1.2014	0.3267	0.3588	0.9272	45

Table 3. Comparison of measurements of right versus left femora from Bab edh-Dhra'.

Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Left	7	0.8950	16.9422	42.5979	< 0.0001	12.0230	-59.8407
Right	9	0.9313	13.9570	94.8890	< 0.0001	13.2031	-96.5021
Combined	13	0.8798	16.8548	80.4790	< 0.0001	13.2435	-91.3103

Table 4. Regression equations based on the vertical head diameter (*PI*) of the Bab edh-Dhra' sample. Length is the dependent variable (*y*) and *PI* is the independent variable (*x*).

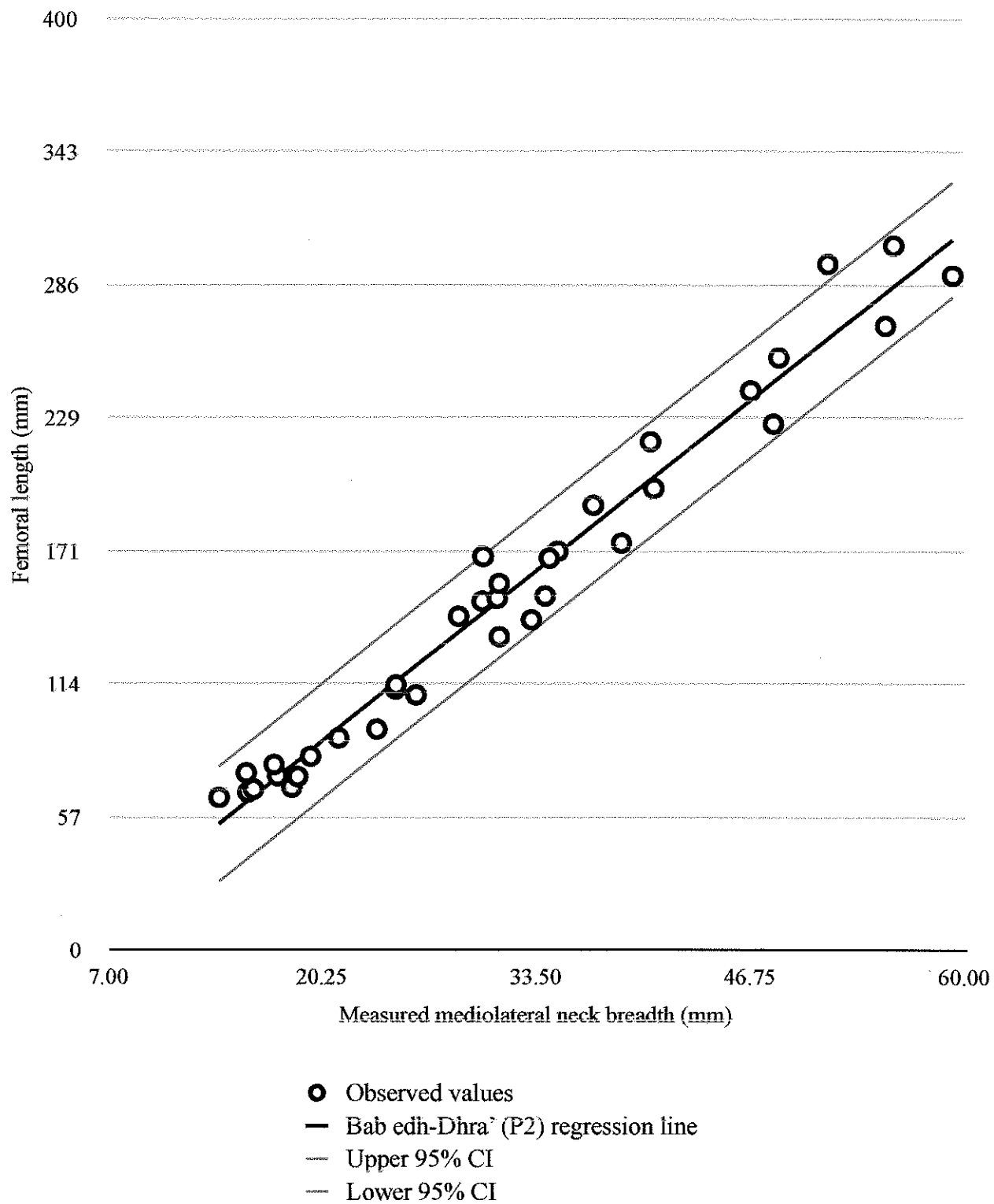
Figure 4. Regression equation based on the vertical head diameter (*PI*) of combined left and right femora of the Bab edh-Dhra' sample, $y = 13.2435x - 91.3103$.



Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Left	20	0.9777	12.1174	790.1987	< 0.0001	5.5163	-18.8172
Right	27	0.9694	12.6407	784.0953	< 0.0001	5.3938	-21.1769
Combined	35	0.9705	12.5820	1086.508	< 0.0001	5.5193	-22.2293

Table 5. Regression equations based on the mediolateral neck breadth (*P2*) of the Bab edh-Dhra' sample. Length is the dependent variable (*y*) and *P2* is the independent variable (*x*).

Figure 5. Regression equation based on the mediolateral neck breadth (P2) of combined left and right femora of the Bab edh-Dhra' sample.



Measurement	Side	p	t-value	d.f.
ODL	Left	0.8581	0.1823	13
	Right	0.9187	0.1041	13
	Combined	0.9682	0.0402	27
P1	Left	0.8465	0.1982	11
	Right	0.8348	0.2135	11
	Combined	0.7705	0.2952	23
P2	Left	0.5133	0.6736	12
	Right	0.2581	1.1828	13
	Combined	0.1810	1.3746	26

Table 6. Interobserver error for Hasanlu proximal femur measurements.

Measurement	F	<i>p</i>(F)	<i>p</i>	<i>t</i>-value	d.f.
ODL	1.0252	0.4818	0.5727	0.5714	26
P1	0.8571	0.6031	0.6666	0.4367	22
P2	1.0083	0.4913	0.7886	0.2710	25

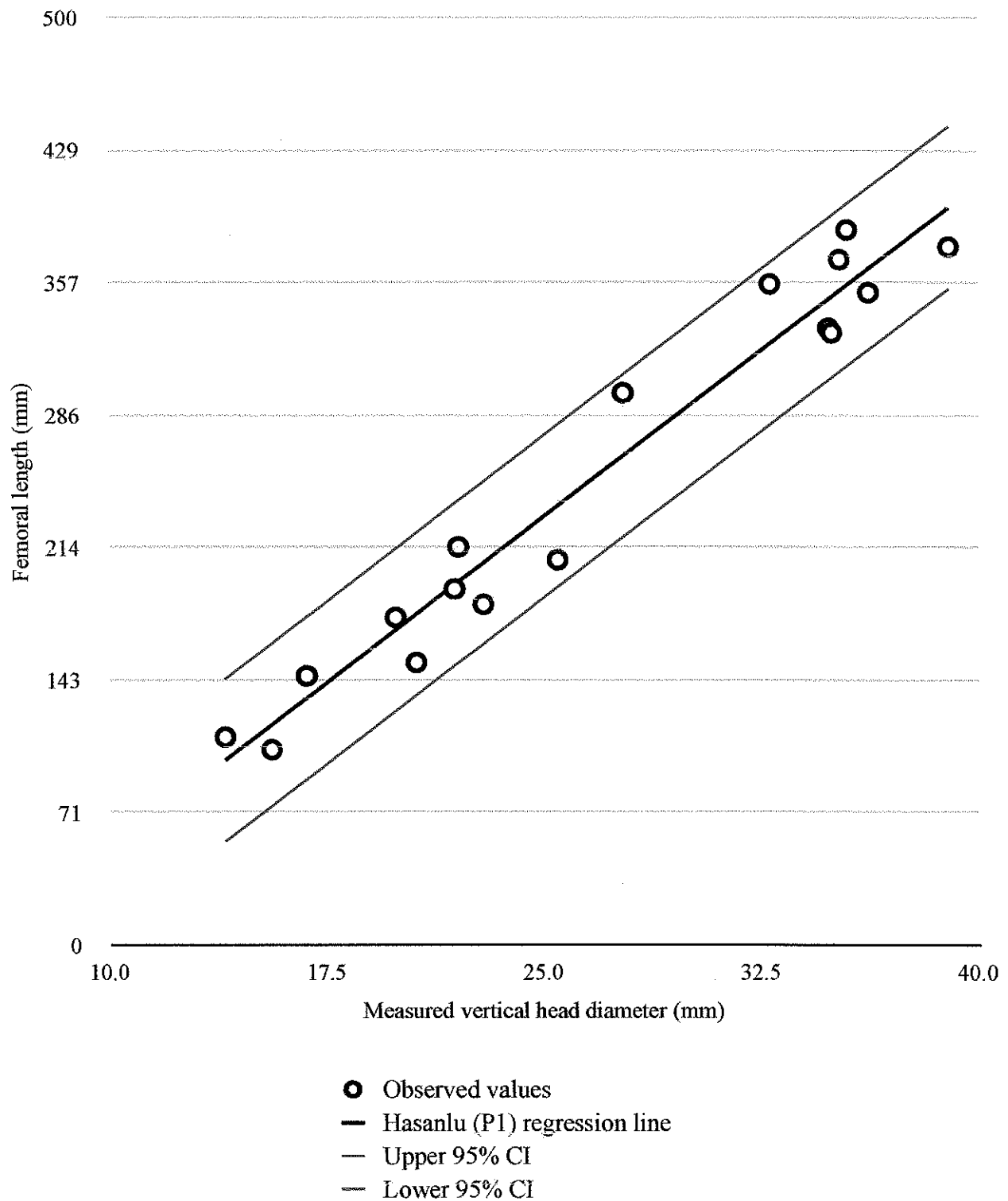
Table 7. Comparison of measurements of right versus left femora from Hasanlu.

Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Left	12	0.9567	21.5918	221.0922	< 0.0001	11.5051	-51.6651
Right	12	0.9660	20.7056	283.8972	< 0.0001	11.5745	-65.5859
Combined	17	0.9541	22.3089	311.5588	< 0.0001	11.9319	-67.7007

Table 8. Regression equations based on the vertical head diameter (*PI*) of the Hasanlu sample.

Length is the dependent variable (*y*) and *PI* is the independent variable (*x*).

Figure 6. Regression equation based on the vertical head diameter (*P1*) of combined left and right femora of the Hasanlu sample.



Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Left	13	0.9881	13.1910	914.6512	< 0.0001	5.4508	-23.9922
Right	14	0.9810	16.3559	620.8801	< 0.0001	5.3722	-24.9383
Combined	20	0.9836	14.8294	1081.138	< 0.0001	5.4711	-26.7885

Table 9. Regression equations based on the mediolateral neck breadth (*P2*) of the Hasanlu sample. Length is the dependent variable (*y*) and *P2* is the independent variable (*x*).

Figure 7. Regression equation based on the mediolateral neck breadth (P2) of combined left and right femora of the Hasanlu sample.

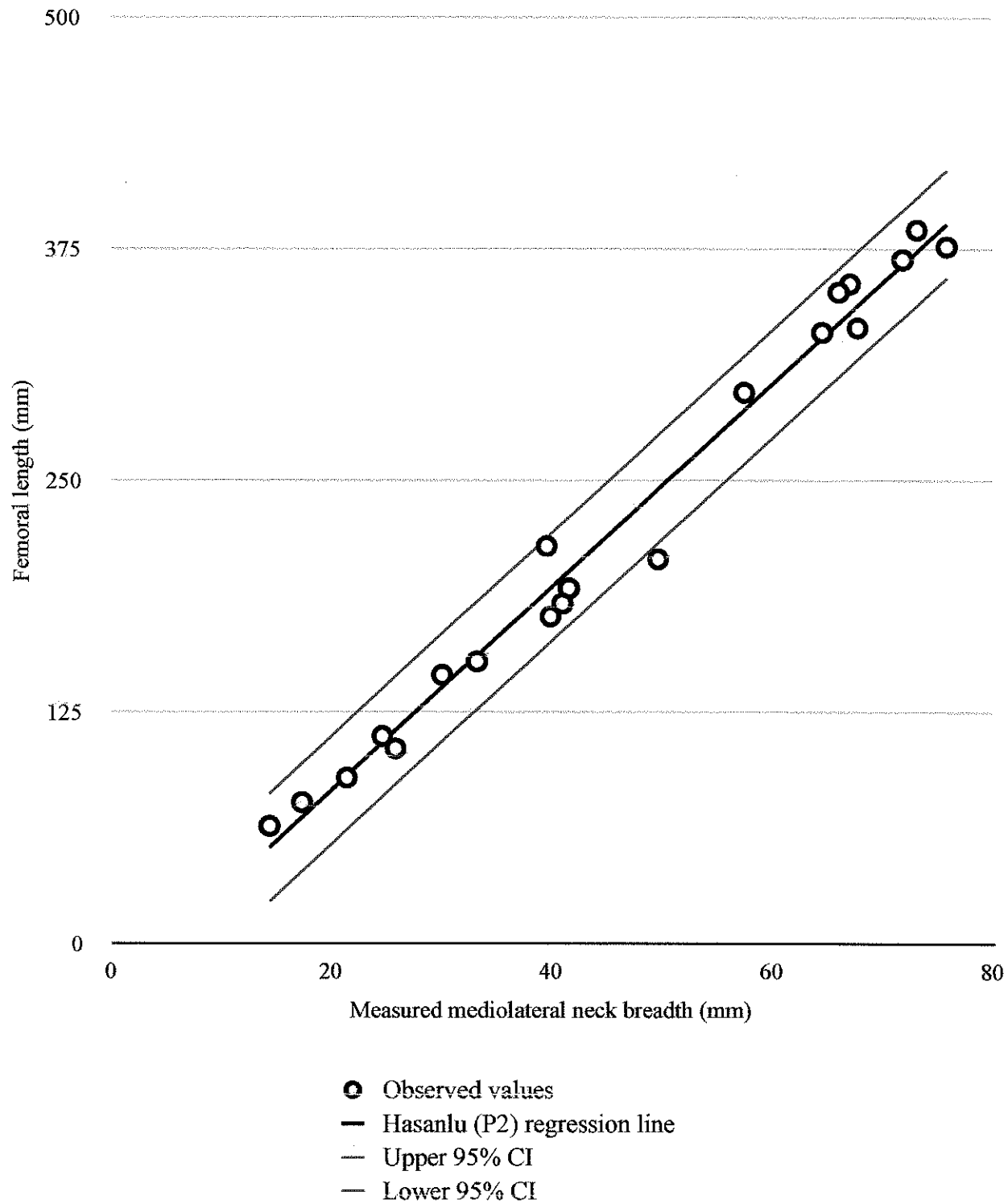


Figure 8. Regression equations for the vertical head diameter (PI).

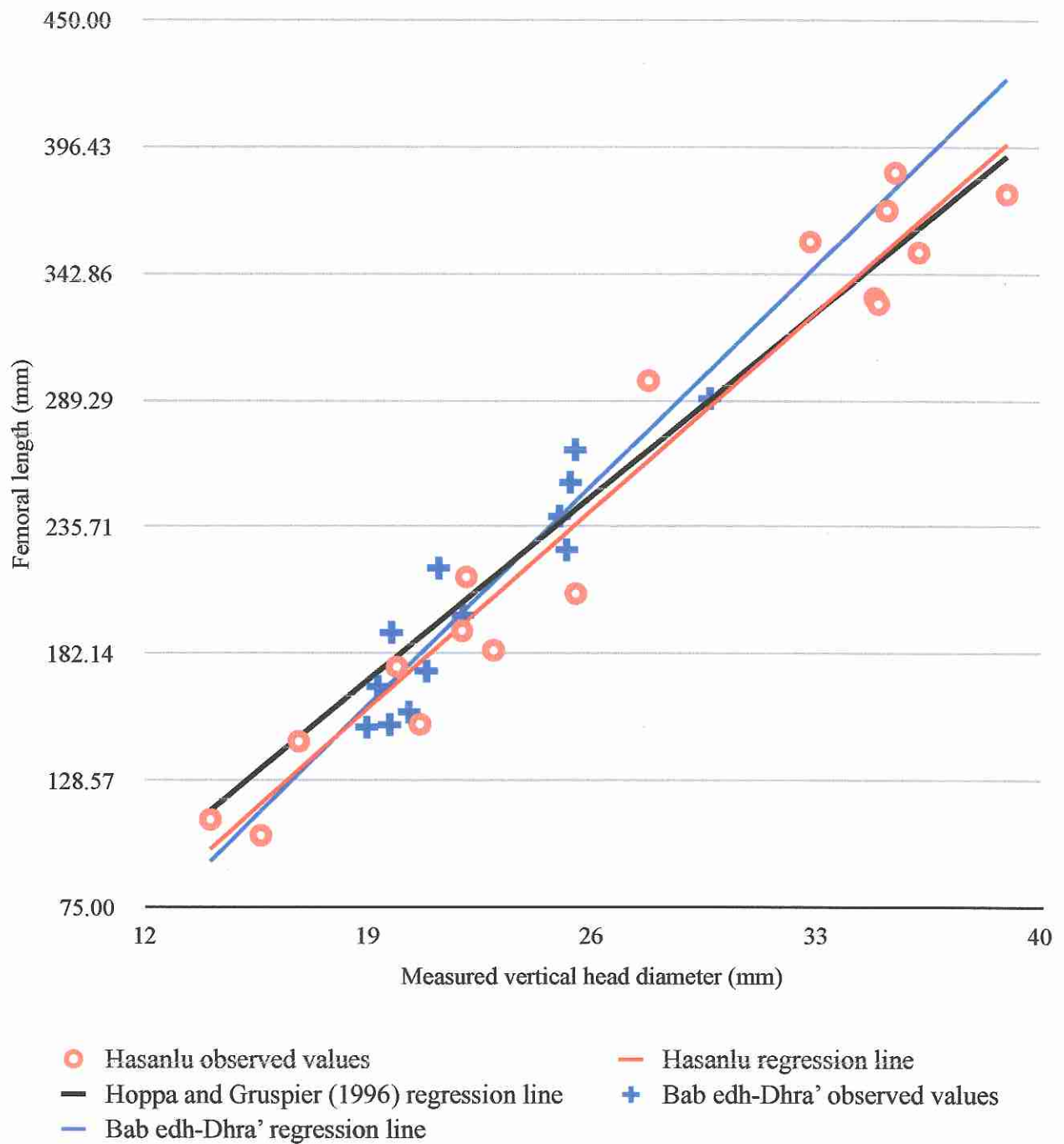
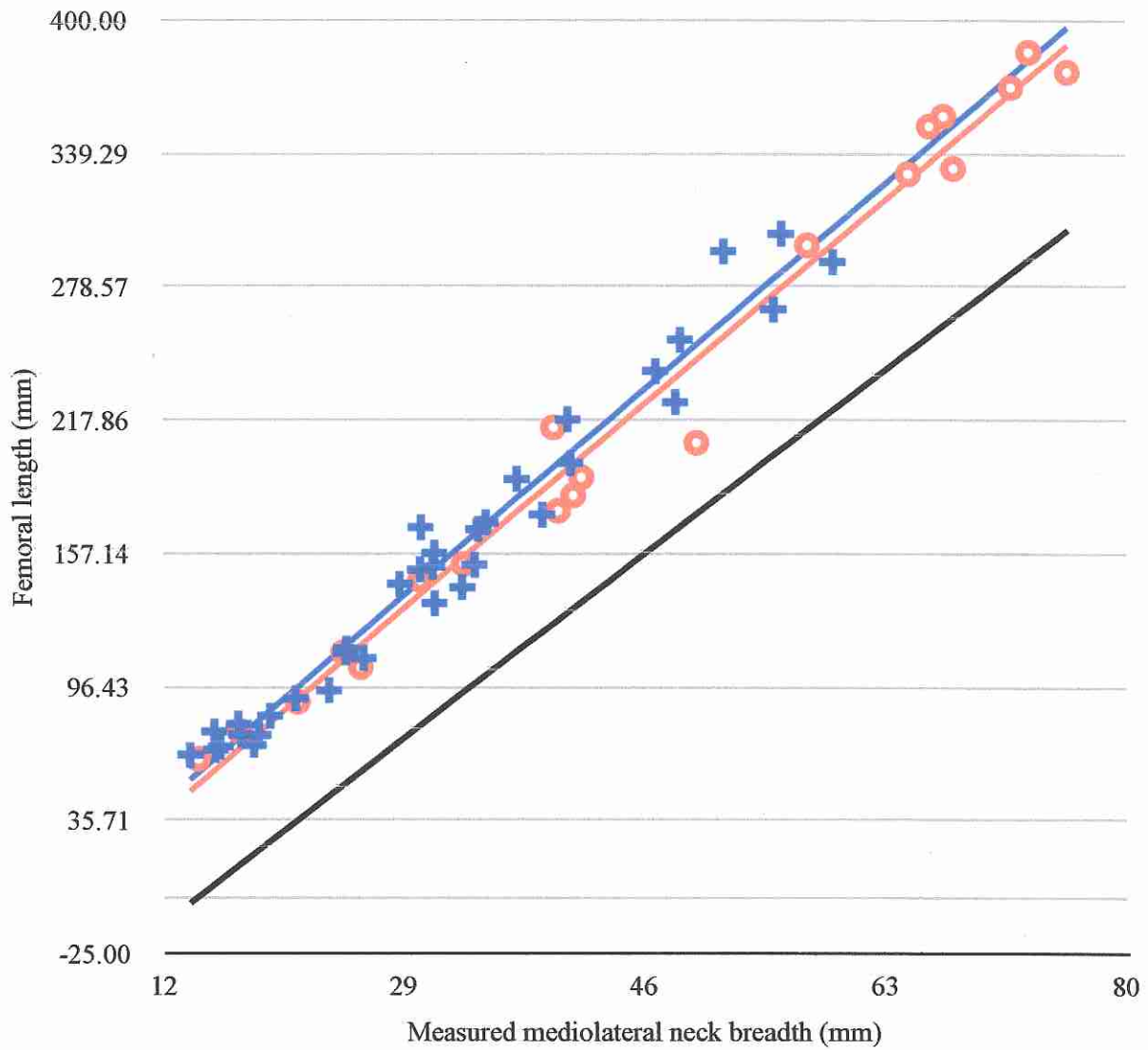


Figure 9. Regression equations for the mediolateral neck breadth (P2).



- + Bab edh-Dhra' observed values
- Hasanlu observed values
- Hoppa and Gruspier (1996) regression line
- Hasanlu regression line
- Bab edh-Dhra' regression line

	Hoppa and Gruspier (1996) equation			Hasanlu equation		
	<i>p</i>	<i>t</i> -value	d.f.	<i>p</i>	<i>t</i> -value	d.f.
P1 estimates	0.5513	0.6130	12	0.2251	1.2790	12
P2 estimates	< 0.0001	27.1933	34	0.0064	2.9055	34

Table 10. Differences between real femoral lengths from Bab edh-Dhra' and those estimated from Hoppa and Gruspier (1996) and Hasanlu regression equations.

Figure 10. Bab edh-Dhra' observed lengths plotted against the Hoppa and Gruspier (1996) and Hasanlu regression equations for *PI*.

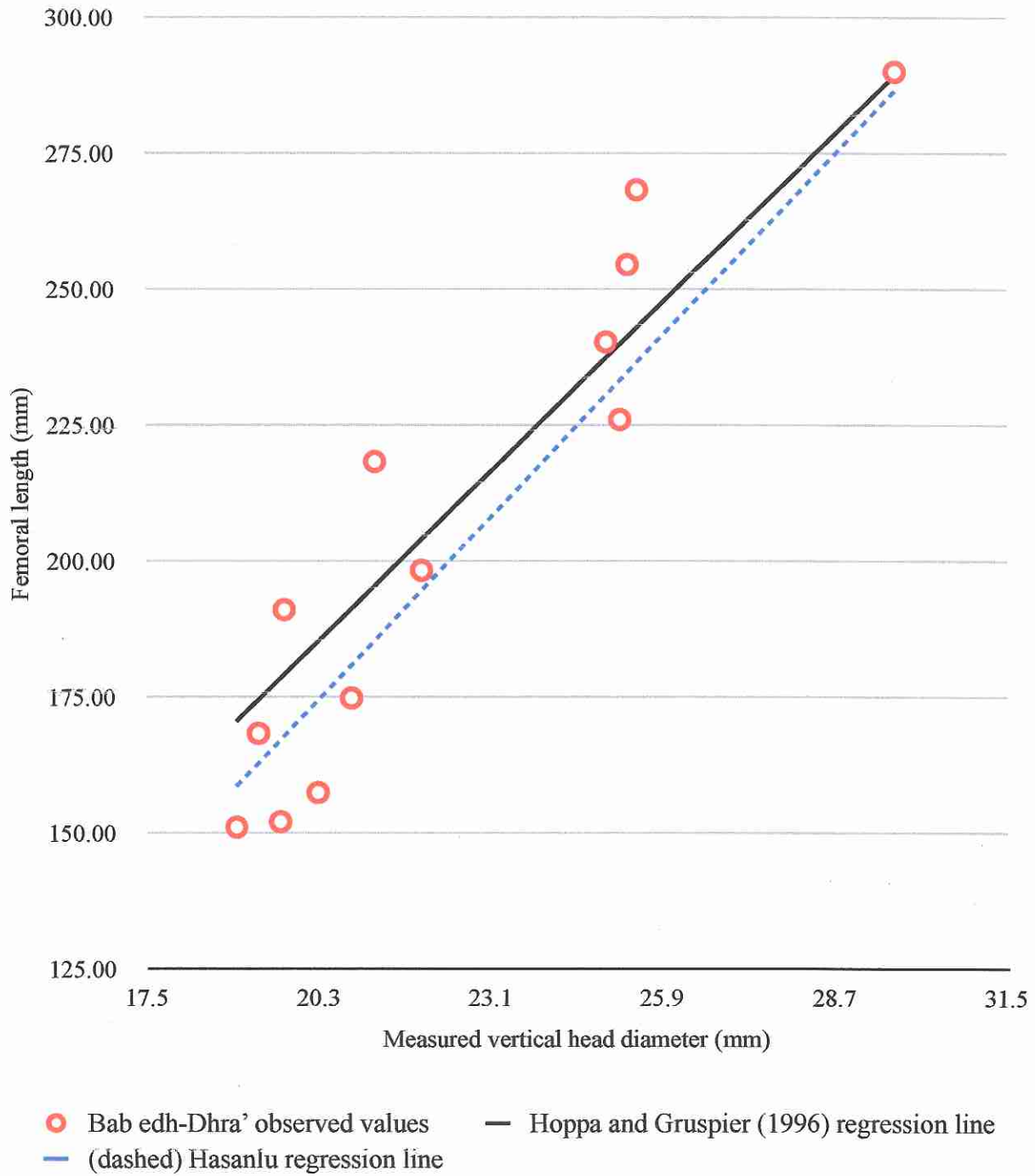
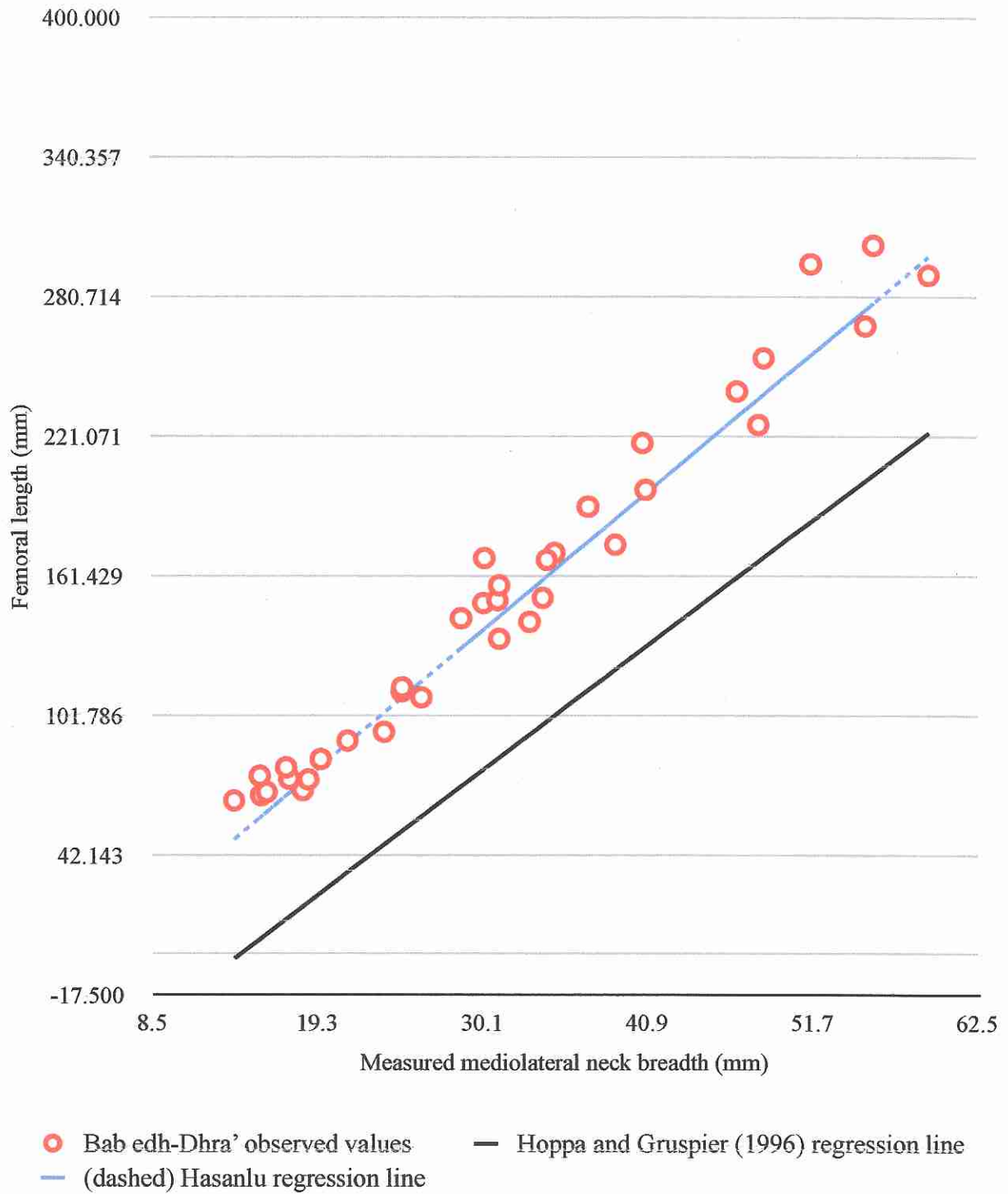


Figure 11. Bab edh-Dhra' observed lengths plotted against the Hoppa and Gruspier (1996) and Hasanlu regression equations for P2.



	Hoppa and Gruspier (1996) equation			Bab edh-Dhra' equation		
	<i>p</i>	<i>t</i> -value	d.f.	<i>p</i>	<i>t</i> -value	d.f.
P1 estimates (all)	0.3536	0.9554	16	0.0661	1.9726	16
P1 estimates (citadel)	0.8933	0.1399	6	0.2887	1.1638	6
P2 estimates (all)	< 0.0001	16.8389	19	0.0495	2.0976	19
P2 estimates (citadel)	< 0.0001	13.1319	7	0.1998	1.4158	7

Table 11. Differences between real femoral lengths from Hasanlu and those estimated from Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations. The "all" sample includes remains from both the cemetery and citadel.

Figure 12. Hasanlu observed lengths plotted against the Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for *PI*.

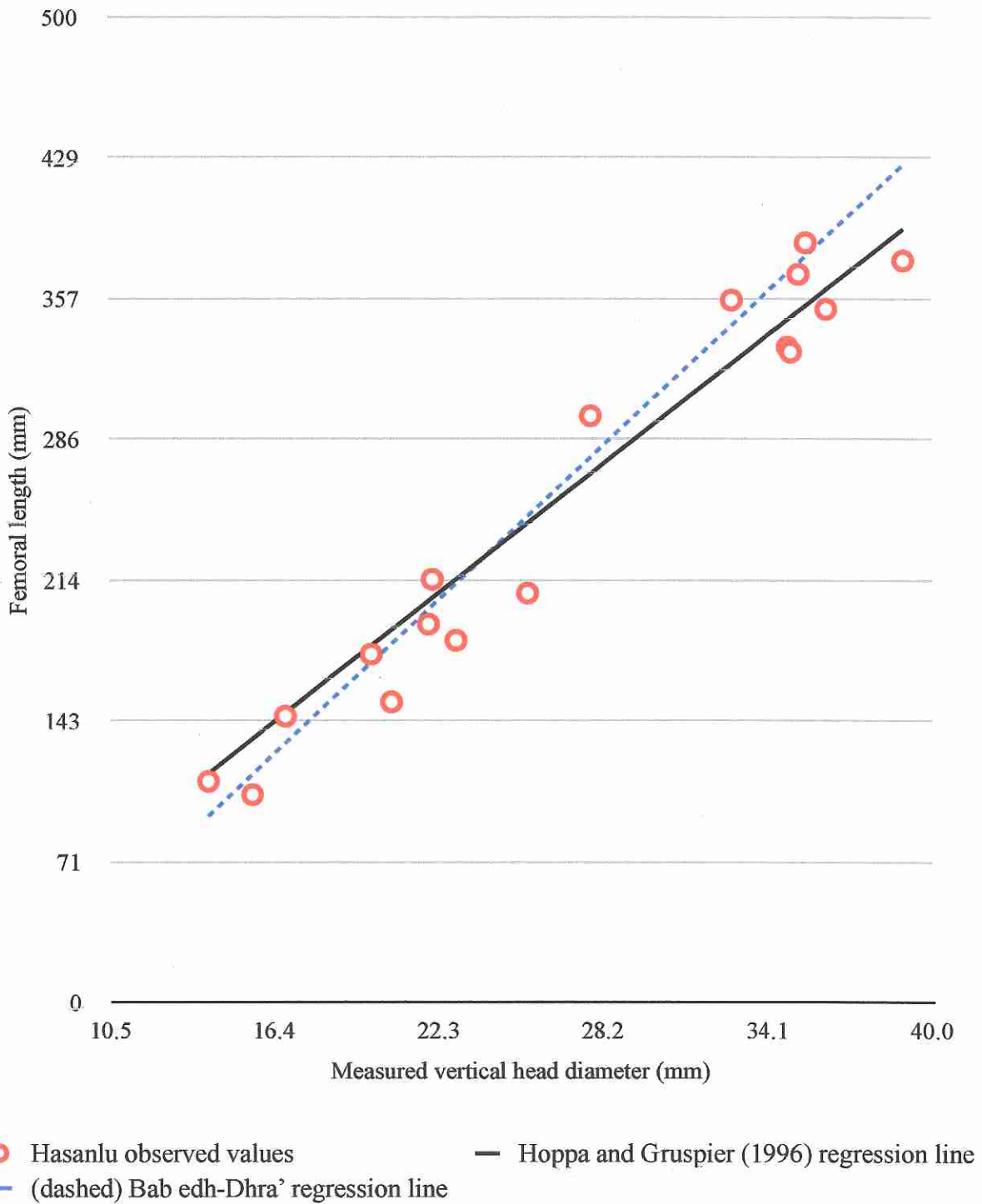


Figure 13. Hasanlu observed lengths plotted against the Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for *P2*.

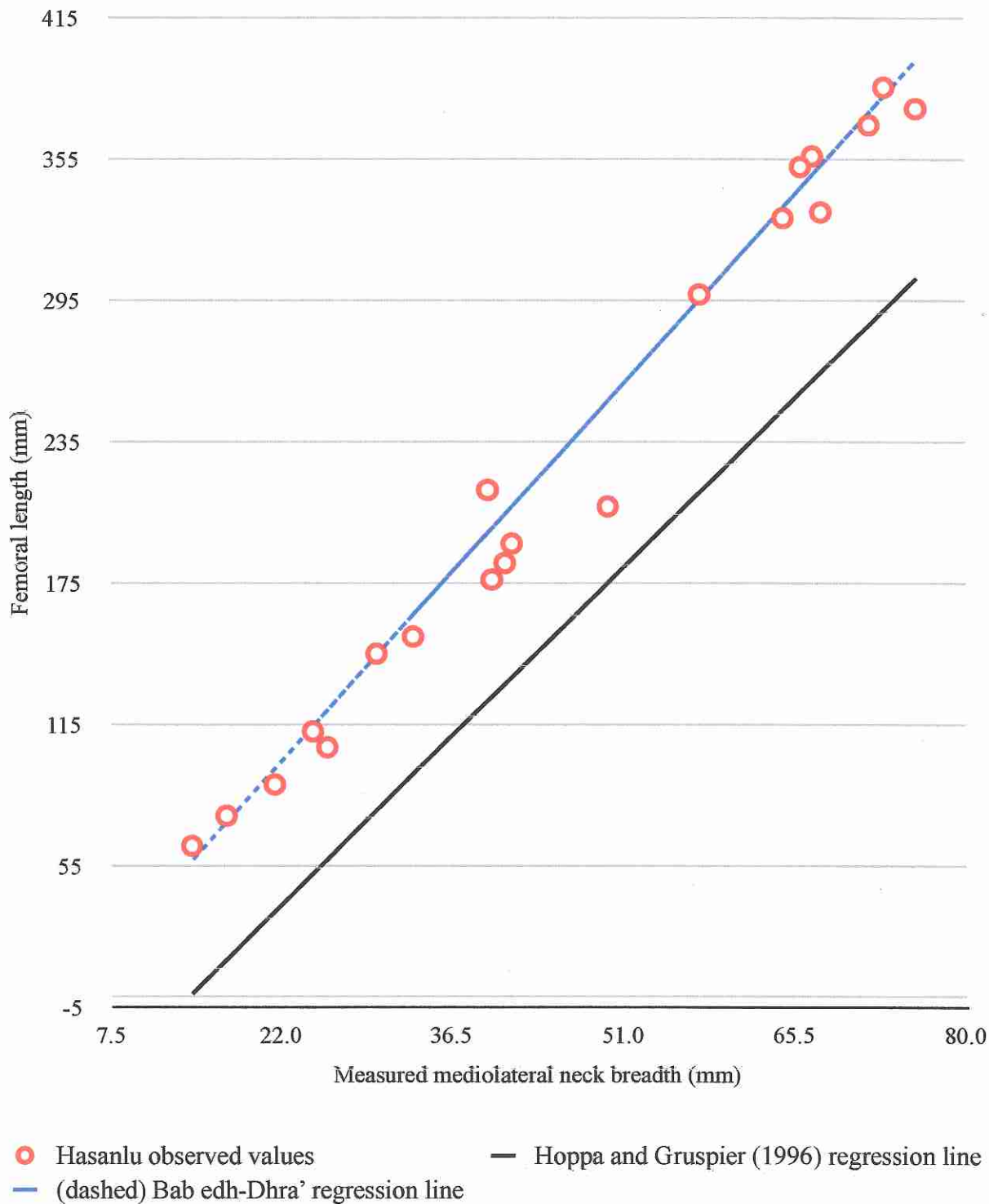
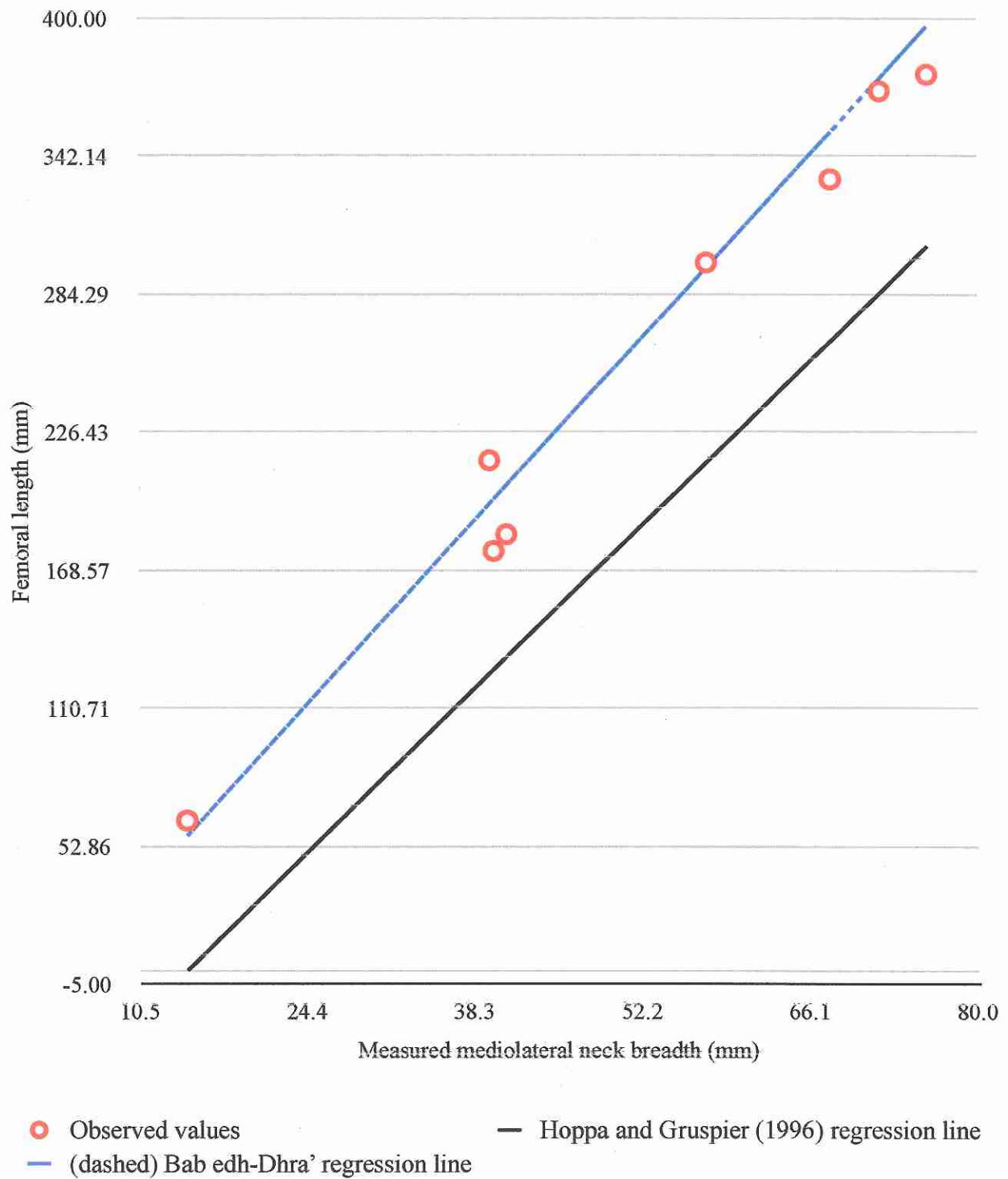


Figure 14. Hasanlu citadel observed lengths plotted against the Hoppa and Gruspier (1996) and Bab edh-Dhra' regression equations for *P2* only.



Measurement	N	R ²	s _e (mm)	F	p(F)	β	α
Vertical head diameter (<i>P1</i>)	30	0.9456	19.8864	486.9194	<0.0001	11.9197	-64.8286
Mediolateral neck breadth (<i>P2</i>)	55	0.9802	13.4763	2619.115	<0.0001	5.4193	-20.9911

Table 12. Equations based on combined Hasanlu and Bab edh-Dhra' samples. Length is the dependent variable (*y*) and *P1* or *P2* is the independent variable (*x*).

Figure 15. Regression equations for the femoral head diameter (*P1*), based on combined samples.

$p = 0.0003$, t -value = 4.0632, d.f. = 29.

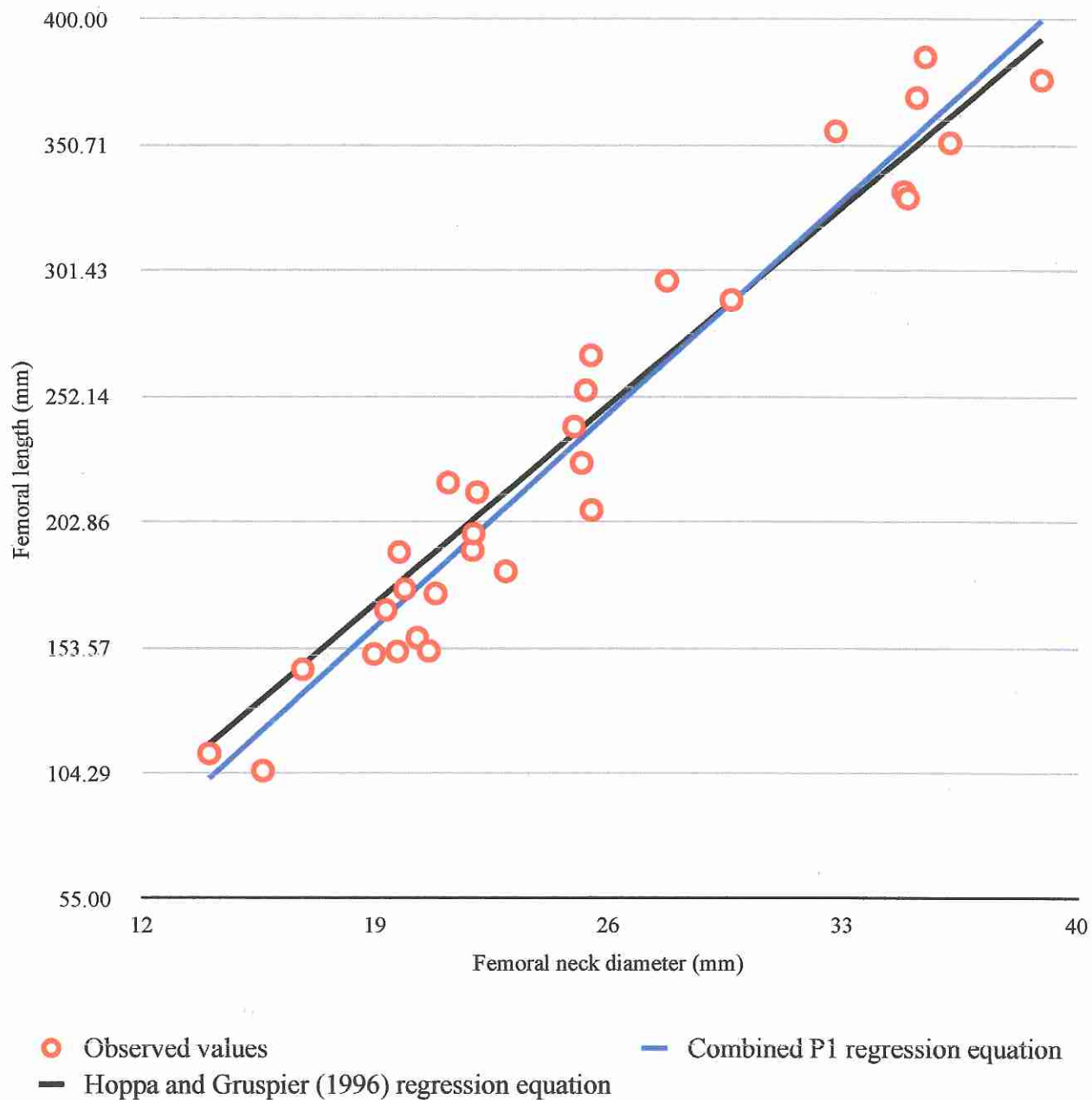
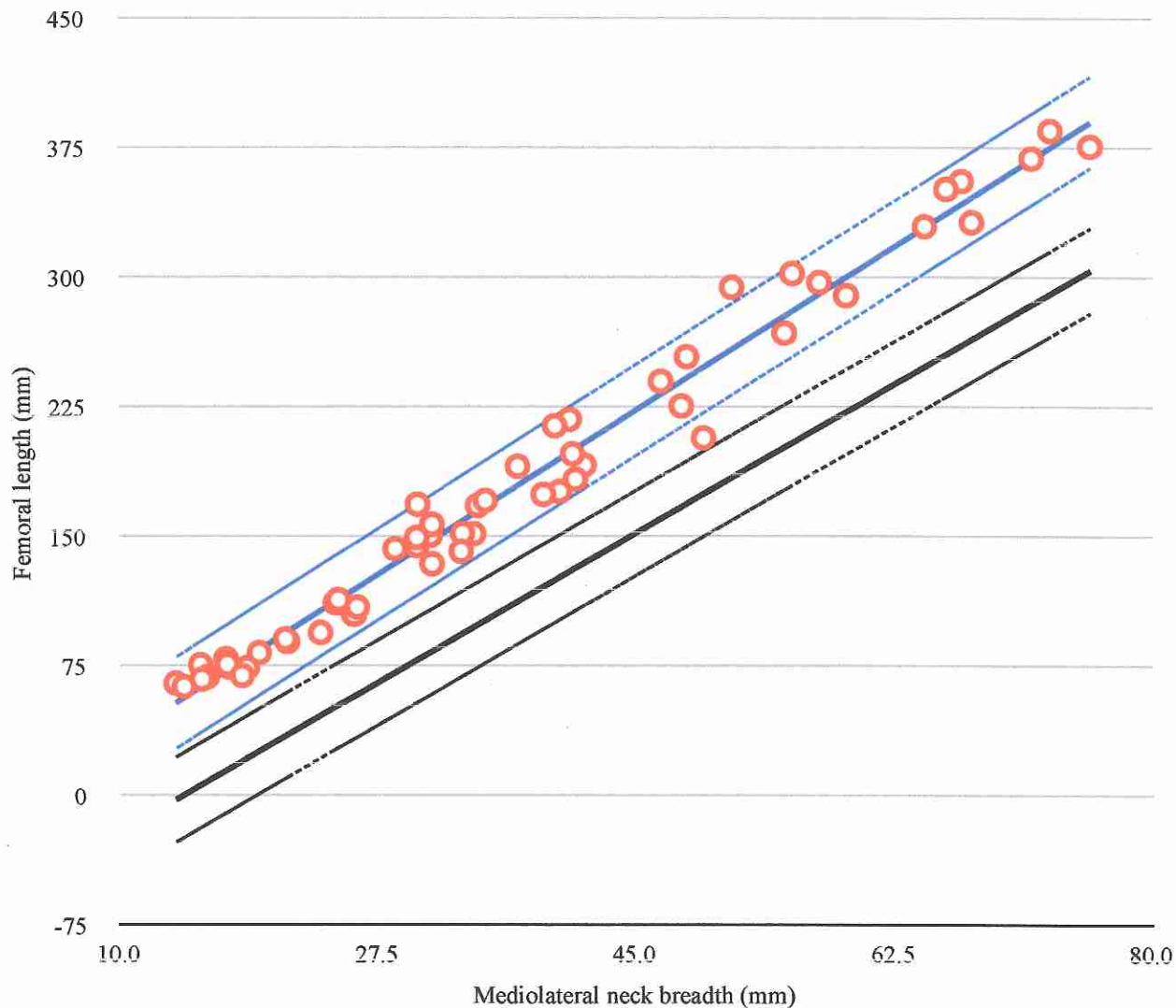


Figure 16. Regression equations for the mediolateral neck breadth ($P2$) including 95% confidence intervals, based on combined samples. Different with $p < 0.0001$, t -value = 57.7769, d.f. = 54.



- Observed values
- Combined P2 regression equation
- - Combined P2 regression equation upper 95% CI
- - Combined P2 regression equation lower 95% CI
- Hoppa and Gruspier (1996) regression equation
- - Hoppa and Gruspier (1996) regression equation upper 95% CI
- - Hoppa and Gruspier (1996) regression equation lower 95% CI

	<i>t</i> -value	d.f.	<i>p</i>	<i>P1 & ODL R</i>	<i>P2 & ODL R</i>	<i>P1 & P2 R</i>
Hasanlu	1.8162	14	0.0908	0.9768	0.9887	0.9864
Bab edh-Dhra'	1.6849	10	0.1229	0.9380	0.9852	0.9615
Combined	2.3270	27	0.0277	0.9724	0.9864	0.9819

Table 13. Comparison of *R* within each sample. This determines whether one *x* (*P1* or *P2*) is a better predictor of *ODL* than the other. *R* values were recalculated so that degrees of freedom were the same for all *R* values used in the calculations.

Data

Key to data:

Mus #: museum number

Bur #: burial number

S: side

Loc: location

R: right

L: left

CV: Catalina I. Villamil measurement

CT: Cassandra M. Turcotte measurement

A: average

ODL: observed diaphyseal length (mm)

P1: femoral head diameter (mm)

P2: mediolateral neck breadth (mm)

UK: unknown

Cem: cemetery

Cit: citadel

Bab edh-Dhra' ages were recorded from pre-determined/card ages.

Hasanlu ages were taken from Smay (2005).

Bab edh-Dhra' EBI Data

Tomb ID	Bur #	Age	S	CV ODL 1	CV P1 1	CV P2 1	CV ODL 2	CV P1 2	CV P2 2	A ODL	A P1	A P2
A100E	72	9 to 11	R	290.00	30.18	58.30	290.00	30.20	59.33	290.00	30.19	58.82
A100E	72	9 to 11	L	290.00	29.18	59.33	290.00	30.19	59.33	290.00	29.69	59.33
A100E	58	Fetal	R	67.70	-	15.61	67.68	-	15.61	67.69	-	15.61
A100S	1	7 to 9	R	296.00	-	52.50	295.50	-	52.50	295.75	-	52.50
A100S	1	7 to 9	L	295.00	-	51.20	294.50	-	52.10	294.75	-	51.65
A102E	1	6 to 7	R	240.00	25.00	46.83	240.50	25.00	46.83	240.25	25.00	46.83
A102S	60	0.5	R	110.00	-	26.05	109.00	-	26.25	109.50	-	26.15
A105NE	42	1	R	135.00	-	31.23	134.00	-	31.23	134.50	-	31.23
A107E	64	Perinatal	R	74.93	-	18.70	73.90	-	18.71	74.42	-	18.71
A107S	1	10 to 12	L	302.50	-	55.19	303.00	-	56.23	302.75	-	55.71
A108NE	5a	9	L	268.00	-	55.18	268.50	-	55.18	268.25	-	55.18
A108NE	5a	9	R	264.50	26.05	52.08	267.00	24.96	52.06	265.75	25.51	52.07
A110NE	I	6 to 9	L	255.00	25.01	48.88	254.00	25.68	48.28	254.50	25.35	48.58
A110NW	II	1.5	R	116.00	-	23.87	116.00	-	23.72	116.00	-	23.80
A110NW	II	1.5	L	114.00	-	24.98	113.50	-	24.83	113.75	-	24.91
A110NW	III	.5-1.5	L	112.00	-	24.85	112.00	-	24.88	112.00	-	24.87
A110NW	III	.5-1.5	R	111.50	-	24.98	112.00	-	24.89	111.75	-	24.94
A110NW	IIIa	Perinatal	R	83.50	-	19.55	82.70	-	19.51	83.10	-	19.53
A110NW	IV	Late fetal	R	65.48	-	13.77	65.31	-	13.89	65.40	-	13.83
A110SE	VI	3 to 5	L	191.00	19.78	36.90	191.00	19.70	37.25	191.00	19.74	37.08
A110SE	IV	2	L	142.50	-	28.81	144.00	-	28.69	143.25	-	28.75
A110SE	50	Perinatal	R	75.00	-	16.29	74.91	-	16.16	74.96	-	16.23
A110SE	50	Perinatal	L	75.00	-	17.47	74.44	-	17.44	74.72	-	17.46
A110SE	51	Late fetal	R	69.71	-	18.41	69.95	-	18.29	69.83	-	18.35
A111E	I	Birth-0.5	R	95.00	-	23.53	94.50	-	23.87	94.75	-	23.70
A111E	4	Perinatal	L	79.65	-	17.42	79.47	-	17.08	79.56	-	17.25
A111N	50	4.5-5.5	R	226.00	25.06	48.07	226.00	25.37	48.36	226.00	25.22	48.22
A111N	53	2.5-4.5	L	218.00	21.32	40.45	218.50	21.11	40.80	218.25	21.22	40.63
A111N	51	.5-2.5	R	170.00	-	30.04	168.00	-	30.47	169.00	-	30.26
A111N	52	1.5-2.5	L	151.00	18.78	31.12	151.00	19.14	31.10	151.00	18.96	31.11
A111W	II/2	3	R	152.00	19.35	34.08	152.00	19.99	34.07	152.00	19.67	34.08
A114N	III	3	L	174.50	20.94	38.78	175.00	20.71	38.88	174.75	20.83	38.83
A114N	III	3	R	173.00	20.43	38.51	173.50	20.78	38.91	173.25	20.61	38.71
A114N	4a	.25-.75	R	91.50	-	21.23	91.00	-	21.03	91.25	-	21.13
A114N	4a	.25-.75	L	91.00	-	21.33	91.00	-	21.31	91.00	-	21.32
A114N	IV	Perinatal	R	71.00	-	15.72	69.91	-	16.01	70.46	-	15.87
A114N	IV	Perinatal	L	69.02	-	16.00	69.02	-	15.93	69.02	-	15.97

Bab edh-Dhra' EBI Data

Tomb ID	Bur #	Age	S	CV ODL1	CV P1 1	CV P2 1	CV ODL 2	CV P1 2	CV P2 2	A ODL	A P1	A P2
A79N	60	5-1.5	L	149.50	-	30.20	150.00	-	30.20	149.75	-	30.20
A79S	3	2-2.5	R	171.50	-	34.35	171.00	-	35.40	171.25	-	34.88
A80S	50(2)	4 to 5	R	167.50	18.88	34.35	169.00	19.75	34.34	168.25	19.32	34.35
A80S	1	3 to 4	R	157.50	20.80	36.50	160.50	19.75	36.44	159.00	20.28	36.47
A80S	1	3 to 4	L	157.25	-	31.23	157.50	-	31.23	157.38	-	31.23
C11	I	5-6 (Dental), 1.5-4.5 (Metrics)	L	198.00	21.93	40.83	198.50	22.03	40.82	198.25	21.98	40.83
C11	I	5-6 (Dental), 1.5-4.5 (Metrics)	R	198.00	21.92	40.81	198.00	21.74	41.24	198.00	21.83	41.03
C11	50	Perinatal	L	76.00	-	15.40	76.00	-	15.64	76.00	-	15.52
C11	50	Perinatal	R	76.00	-	16.91	76.00	-	16.53	76.00	-	16.72
G004	60	1.5-3	R	142.00	-	33.52	141.50	-	32.91	141.75	-	33.22

Hasanlu Data

Mus #	Bur #	Age	Loc	S	CV ODL	CV P1	CV P2	CT ODL	CT P1	CT P2	A ODL	A P1	A P2
65-31-728	VIEB19	3-6	Cem	L	192.50	22.60	41.38	191.00	21.29	41.82	191.75	21.95	41.60
65-31-730	VIGB5	1-3	Cem	R	112.00	14.41	23.50	112.00	13.63	25.94	112.00	14.02	24.72
65-31-731	CC31B2	fetal - 1	Cit	L	63.05	-	14.25	63.77	-	14.50	63.41	-	14.38
65-31-735	VIEB14	fetal - 1	Cem	L	105.50	15.29	25.91	105.00	15.94	25.96	105.25	15.62	25.94
65-31-735	VIEB14	fetal - 1	Cem	R	106.00	15.54	25.91	105.00	15.53	25.96	105.50	15.54	25.94
65-31-760	VIHB8	12-17	Cem	L	351.00	36.31	-	352.50	36.15	-	351.75	36.23	-
65-31-760	VIHB8	12-17	Cem	R	350.00	35.85	65.95	350.00	36.58	66.30	350.00	36.22	66.13
65-31-761	VIB11	6-12	Cem	L	330.00	34.76	64.89	330.00	35.16	64.39	330.00	34.96	64.64
65-31-762	VIHB5	6-12	Cem	L	355.50	32.37	67.17	357.00	33.30	67.14	356.25	32.84	67.16
65-31-762	VIHB5	6-12	Cem	R	356.00	34.10	67.46	355.00	33.50	66.60	355.50	33.80	67.03
65-31-766	VIHB4	1-3	Cem	L	145.00	16.78	30.24	145.00	16.86	30.13	145.00	16.82	30.19
65-31-766	VIHB4	1-3	Cem	R	144.00	17.65	30.31	145.00	17.43	30.20	144.50	17.54	30.26
65-31-779	W18-19 B5	3-6	Cit	R	184.00	23.02	41.63	183.00	22.84	40.40	183.50	22.93	41.02
65-31-780	VIEB18	fetal - 1	Cem	L	90.00	-	21.43	89.00	-	21.46	89.50	-	21.45
65-31-780	VIEB18	fetal - 1	Cem	R	90.00	-	21.71	90.00	-	21.72	90.00	-	21.72
65-31-781	W18-19 B3	6-12	Cit	L	297.00	27.94	58.09	298.00	27.62	56.99	297.50	27.78	57.54
65-31-782	VIGB4	3-6	Cem	R	152.50	20.03	33.02	152.00	21.20	33.59	152.25	20.62	33.31
69-33-5	unknown	fetal - 1	UK	R	75.96	-	17.78	76.48	-	16.89	76.22	-	17.34
71-23-523	HAS70 SK288 W30B9	6-12	Cit	R	368.00	35.22	72.35	371.00	35.25	71.51	369.50	35.24	71.93
71-23-528	HAS70 SK304	6-12	Cit	L	214.00	22.19	40.24	215.00	21.99	39.00	214.50	22.09	39.62
71-23-528	HAS70 SK304	6-12	Cit	R	212.00	21.96	41.35	213.00	21.94	40.19	212.50	21.95	40.77
71-23-532	W29B1a	3-6	UK	R	208.00	25.54	50.13	207.00	25.48	49.30	207.50	25.51	49.72
75-29-514	HAS74 W23E (3) B9	?	UK	L	385.00	35.32	72.83	386.00	35.67	73.56	385.50	35.50	73.20
75-29-523	HAS74 SK362 W23 E3 B15	6-12	Cit	L	333.00	35.21	67.83	332.00	34.48	67.86	332.50	34.85	67.85
75-29-523	HAS74 SK362 W23 E3 B15	6-12	Cit	R	332.00	35.77	70.48	330.00	35.63	69.54	331.00	35.70	70.01
75-29-532	HAS74 SK417 X20B4a	3-6	Cit	L	177.00	20.19	39.98	176.00	19.61	39.89	176.50	19.90	39.94

Hasanlu Data

Mus #	Bur #	Age	Lec	S	CV ODL	CV P1	CV P2	CT ODL	CT P1	CT P2	A ODL	AP1	AP2
unknown	HAS74 X20B5	UK	Cit	L	377.00	38.76	75.81	376.00	39.21	76.00	376.50	38.99	75.91
unknown	HAS74 X20B5	UK	Cit	R	378.50	39.87	76.81	379.00	39.56	75.90	378.75	39.72	76.36