Project in Biomedicine at ADBOU - University of Southern Denmark

Height Estimation from Skeletal Remains

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Indhold

Summary

This paper examines the relationship between adult height and femur length. This is done by using linear regression analysis, which is a useful tool in forensic medicine and biological anthropology, and which has been used by scientists as far back as 1899. This paper finds a strong linear association between femur length and height.

The regressions found for men and women are as follows:

$$Height_{men} = 2.610 \cdot femur + 44.201$$

$$Height_{women} = 2.019 \cdot femur + 67.579$$

The material used in this paper is from *Gråbrødre* in Ribe and a total of 114 individuals are included, 67 males and 47 women.

Linear enamel hypoplasias are indicators of an individual's past episodes of poor health and possibly growth disturbance. The enamel of permanent teeth forms during childhood and does not remodel once formed. Intense periods of disease and nutritional stress can cause interruptions in the enamel formation, producing a band of reduced enamel thickness, called hypoplasias. It is examined how childhood illness affect body proportions by looking at the hypoplasias of the material and their relation to body proportions. The examination of the material in this paper does not indicate that body proportions are altered in individuals with hypoplasias. Some hypoplasias could be caused by non serious weakness periods while others are caused by serious illness which manifests in growth development. It can therefore not be concluded that these do not have any correlation what so ever, since it is not possible to know the type of illness from looking at the hypoplasias.

Conclusively, the result on the height/femora relation is compared to those of Boldsen and was found to show very similar tendencies. This supports the robustness of using femora as a tool for predicting height of an individual.

Introduction

Height estimation from skeletal remains is a useful tool in forensic medicine and biological anthropology. Height calculation from femur length using regression was first carried out by Pearson in 1899 and a number of scientists have followed [1]. A number of factors are hypothesized to have an impact on adult height. These include factors such as genetic background, nutrition, and disease. One of the most used statistical methods in physical anthropology is regression analysis and it has been recommended by *Konigsberg et al.* using regression of stature on bone length(s) [2]. To examine the impact of childhood illness one could look at the dental enamel for linear enamel hypoplasias to see if this has an effect on the adult height.

Linear enamel hypoplasias are transversal deficiencies of enamel thickness and are related to periodic physiological disruption to the enamel matrix secretion during teeth development. They are caused by a developmental defect of enamel that occurs during the process of amelogenesis, which is enamel formation. A number of factors can cause linear enamel hypoplasias, but often, they result from interactions between systemic illness and under-nutrition [3].

The purpose of this paper is to collect data from skeletons from Ribe Cemetery, to analyze the data and examine the association between adult height and femur length using regressions analysis. Furthermore, it is investigated whether periods of weakness in childhood, in this paper from the age 1-6 inclusive, manifested as hypoplasias, have an impact on adult height and body proportions.

Ribe

Ribe is the oldest town in the North and is located by Ribe creek in Jutland, Denmark. The town has existed since the 8th century where it was strategically placed in means of expeditions and trade. It can be traced back to year 705 were a trade center were positioned near the northern side of Ribe creek [4, 5]. The area around Ribe consists of hills from the Saale ice age and heath from the Weichsel-glacier [4]. Although the city has played a key role in the Christian church's story in Denmark, the medieval Ribe was not a religious center of same importance as Lund and Roskilde [4]. The town was greatly expanded in the Medieval and became a center for trade, administration, and religion. Due to this fact, Ribe has a substantial amount of written sources the medieval [4]. From the middle of the seventeenth century the great period of Ribe was over, and the city became a small provincial town [5].

Ribe in the medieval was a large trade center with a large harbor and connections with the rest of Europe. It has had great influence on the Christian church in Denmark and was discovered early by the European church. In the 9th the respected missionary Ansgar acquired a church site and since then a number a great number of churches emerged in Ribe. The Ribe Cathedral was begun built in 1150-1175 and was finished in 1225-1250 [6]. In the first half of the second millennium the cathedral was Jutland’s main church [4]. In the 13th the Dominicans and Franciscans created monasteries in Ribe [4].

The Franciscan, or “Gråbrødre”, came to Denmark in year 1232 and Ribe was the first town where the order created a Danish monastery. The founder of the monastery was Johannes Scolaticus who also helped the monks acquire the site for their monastery. The church was opened in year 1280 and was dedicated to Saint Laurentius [4].

In summary, there were a number of religious institutions in Ribe; Ribe Cathedral, Saint Mikkels church, the Benedict nun monastery, the Dominican monastery, the Franciscan monastery, and others [4]. The churchyard from which the material in this paper has been excavated was used from about 1200 to 1400 and is said to be Franciscan though it is unclear which church the excavated cemetery belonged to.

Ribe is the best preserved town from the medieval and still has a number of buildings from the previous centuries including Ribe Cathedral, several watermills, friaries, and houses. The only town in Denmark with more preserved buildings than Ribe is Copenhagen, which is also the largest town in Denmark [5].

The Ribe Cathedral has received 3 stars in the Michelin Guide, which is the highest score and shows that the Cathedral is definitely worth an excursion due to its magnitude and significant history [7]. Ribe is indeed a great cultural environment [5].

Material and Methods

The skeletons used as material in this analysis where excavated from a Medieval cemetery in Ribe in Jutland, Denmark from Gråbrødre Kloster in 1993 with Jacob Kieffer-Olsen as leader of the excavation. A total of 429 graves where excavated and of those the height in the grave could be measured on 184 individuals. Of the 184 individuals 114 individuals (67 men and 47 women) were adults and available to this analysis. The method used to measure the height is proposed by Boldsen in 1984. The height is measured on skeletons in an extended supine position that are of acceptable preservation and have not been disturbed. The measurement is taken using a folding rule placed from above the cranial point farthest from the body and to the most distal point of the talus [8]. This method used to measure the stature of an individual has been investigated and is concluded to be a reliable method in measuring the height of an individual [8].

Only adult skeletons are included in this paper since fully grown individuals are needed to measure adult height. An adult is here defined as an individual were the sphenooccipital synchondrosis (SOS) and all the epiphysis on the long bones have fused [9].

Age and sex estimation have been performed on all the individuals enrolled in analysis. This information is used in further analyses. The methods used for sex estimation and age estimation at death are described in *Osteological Methods – Report Manual* [10]. Some of the material was exhibited at Ribe Museum and was therefore not available.

Enamel Formation and Enamel Hypoplasia

Growth and development are amongst other linked with nutrient intakes, immune function, disease exposures, and energy expenditures, therefore height and body proportion of an individual are said to be affected by periods of weakness in infantry. Periods of weakness in infancy affects the enamel formation on the teeth in form of enamel hypoplasias, which enables the identification of illness at childhood from skeletal remains [3].

Dental enamel consists of multiple layers which are laid down in series from the dentine horn and continues cervically.

Enamel formation begins with ameoblasts (enamel forming cells) lining up opposite odontoblasts (dentin-forming cells) along the inner enamel epithelium. The odontoblasts then form a platform of dentin matrix and the ameoblasts start secreting enamel. The first layers of enamel make up the cuspal enamel. When the cuspal enamel has been depositioned the ameoblasts, which are lined up along the cusp’s occlusal surface, enter their secretory phase and play a role in the maturation process of the enamel matrix [11, 12]. If the process of enamel formation is disrupted, enamel hypoplasias develop.

Dental enamel hypoplasias are deficiencies of enamel thickness which can be pits, horizontal lines, or grooves in the enamel and develop if the function of the ameoblasts are compromised during the secretory phase of matrix formation [11, 13]. The differences in hypoplasias result from the difference in how the disruptions affect groups of ameoblasts. Linear enamel hypoplasias are the most common form of enamel hypoplasias and is the form of enamel hypoplasia with the greatest potential to reveal information about enamel growth disturbances [11].

Linear enamel hypoplasias form when the enamel matrix-secreting function of ameoblasts is temporarily disrupted. Linear enamel hypoplasias are used as dental indicators of periods with metabolic stress.

Linear enamel hypoplasias result from disturbances that last several weeks or more [14].

Enamel hypoplasias are used as markers of systemic physiological stress in unworn teeth and allow researchers to evaluate the duration of growth disruptions because the enamel of permanent teeth forms during childhood and do not remodel [11, 14].

Data Collection

Data Treatment

All the information is typed in a formula in Microsoft Office Access 2007 created to this project. See Appendix 1 for an example of the formula.

The data is transferred to SPSS by using the query system in Microsoft Office Access 2007. The database is available at http://mirror.aidoh.dk/mettewod/wod.zip.

Appendix 11 shows the manual for entering scorings into the database for analysis similar to this report.

Hypoplasia

In this paper only the upper left incisor and upper left canine are used to check for hypoplasias, and furthermore linear enamel hypoplasias are defined as a horizontal enamel deficiency visible to the naked eye. Enamel hypoplasias can be difficult to see and the teeth should be examined in both direct and indirect light. Hypoplasias are usually easier to see in indirect light. Picture 1 shows a very good example of enamel hypoplasias. Ideally hypoplasias would line up in this manner as a result of a single incidence of weakness. However normally it is not as clear as Picture 1 shows and hypoplasias are often difficult to see.

Picture 1: Enamel hypoplasias – Individual VKH1201, G371

Only the two largest hypoplasias are used for further investigation. Based on the position of these, a chart taken from ADBOU's *Osteological Methods– Report Manual* [10], is used to determine at what age the hypoplasias have developed. See Appendix 2 for tooth chart.

A tooth is considered *non scorable* when more than one third of the tooth is worn down. When a tooth is so worn down, there is a possibility that a number of hypoplasias are no longer present the tooth is not usable for scoring. If the upper left incisor or upper left canine is missing the upper right incisor and upper right canine is used instead.

The teeth should not be scored if the there is a substantial amount of tartar as this could conceal possible hypoplasias. The examiner is not allowed to remove the tartar.

Appendix 3 shows more pictures of teeth, both scorable and non scorable.

Length of Femur

Besides examining the effect of illness, this thesis examines the association between femur length and adult height. The maximum length of the right and left femora are measured using a measuring table. The length is entered in the database in centimeters with one decimal.

Possible abnormalities on either of the femora that would influence the height measured in the grave should be noted and commented in the database. This could be fractures that have healed abnormally, giving the individual a shorter height than before the fracture and resulting in false adult height. If there are traumas or abnormalities that might affect the adult height it is taken into account when analyzing the data.

The femora should not be measured if they are destroyed or degraded in a manner that will affect the measurement of the length. Appendix 4 shows a femur which is not suited for measurement.

The Vertebras

The vertebras should be checked for collapses or traumas that might influence the height of the individual. If there are abnormalities that may affect the adult height on the vertebras it is noted and taken into account when using the data since this renders the height measured in the grave invalid. This is shown in Appendix 4. Vertebras may collapse in individuals with tuberculosis or osteoporosis.

Results and Data

After having defined the measurements of height, the hypoplasias and femur properties, the data can be analyzed. All data analysis is performed on the data for men and women separately.

A large number of the individuals from the cemetery had hypoplasias (89%). This is a much higher number than in Tirup (44%) which were examined by *Boldsen* [1]. The investigation of Tirup included only hypoplasias on the canine and this investigation includes hypoplasias on both the upper left canine and the upper left incisor. Since there is an increased change of noticing hypoplasias when looking at two teeth opposed to one this could be an explanation to the higher prevalence of hypoplasias

None of the femora or vertebras was found to have fractures or abnormalities that would affect the height of the individual.

Scatterplots

A number of scatter plots were performed, with femur length depending on height, to search for tendencies, outliers, measurement faults, and typos, and to get an overview of the association between these. The scatter plots showed no signs of outliers, nor of any of the faults but showed a clear positive linear tendency. This tendency is examined further in the section Regression Analysis. The scatter plots can be found in Appendix 5.

T-test on femora

It is not always that both femora are available for analysis and to be able to use an individual with only one available femur it has to be tested whether the two femora differ in length. To do this a paired samples t-test was performed between the left and right femora. The t-test was performed with a significance level of 0.05, and showed no difference. This means that there is no significant difference between the two femora. While the mean length is preferred, it is statistically valid to only use a single available femur and let it represent the mean. For the SPSS output for the t-tests, see Appendix 6.

Regressions Analysis

In the scatter plots described above, a clear linear tendency was observed for both male and female individuals, and this is further examined by a regression analysis of the height versus femur length [15].

Linear regression performed on men:

Model Summary

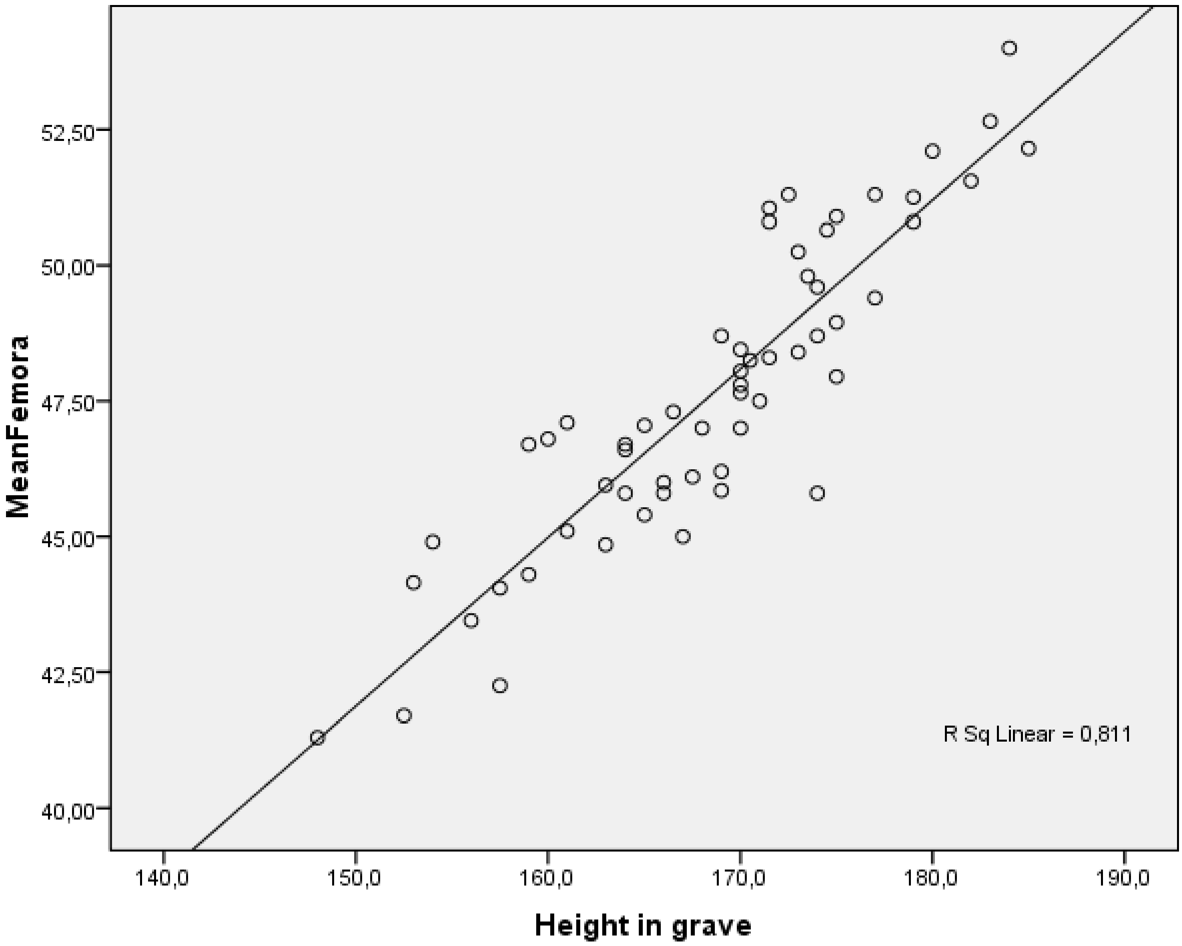
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,901[a]	,811	,808	3,5976

a. Predictors: (Constant), MeanFemora

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	44,201	8,032		5,503	,000
	MeanFemora	2,610	,168	,901	15,518	,000

a. Dependent Variable: Height in grave



Picture 2: Scatter plot of height and mean femora length for men. Also showing the linear regression of height as a function of mean femora length.

The result of the regression analysis performed on all men is shown above. The regression line has been added to the before mentioned scatter plot. By looking at the graph, it seems to describe the data well, which is also confirmed when looking at the coefficient of correlation. It has a value of 0.901 which suggest a strong linear correlation [16].

The regression for calculating the height of a male from the femur or femora is:

$$Height_{men} = 2.610 \cdot femur + 44.201$$

Regression performed on women:

Model Summary

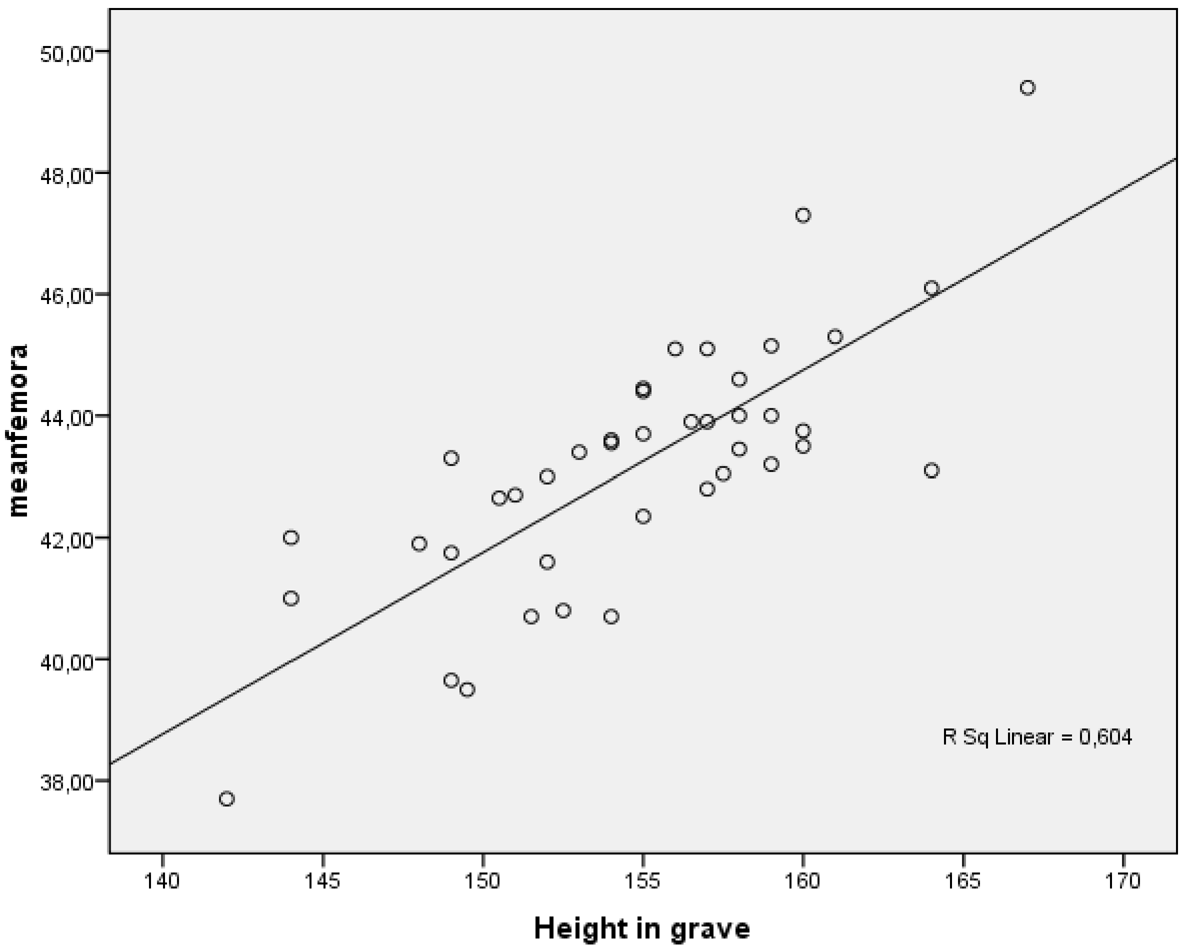
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,777[a]	,604	,594	3,476

a. Predictors: (Constant), meanfemora

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	67,579	11,321		5,969	,000
	meanfemora	2,019	,262	,777	7,714	,000

a. Dependent Variable: Height in grave



Picture 3: Scatter plot of height and mean femora length for women. Also showing the linear regression of height as a function of mean femora length.

The correlation between the height and mean value of femora is also clear in the regression analysis for women. The correlation coefficient is 0.777 which also shows a strong linear tendency. The correlation is not as strong as for men, but this could be a coincidence.
The regression for calculating the height of a female from the femur or femora is:

$$Height_{women} = 2.019 \cdot femur + 67.579$$

T-tests

To investigate whether individuals with hypoplasias should have different body proportions, or in other words a different relationship between height and femur length, it is necessary to examine if the residuals differ in a significant way in those with hypoplasias compared to those without hypoplasias. This is done by comparing the residuals for the linear regression of individuals with and without hypoplasias. First it must be clear whether the individuals with scorable teeth do not have heights or femur lengths that differ from all the individuals. They should representative of the whole data set.
Independent samples t-tests were performed to see whether there is a statistical difference between the heights of individuals with and without scorable teeth. The same was done for femur. For both men and women, t-tests were performed with a significance level of 5%. These showed that there are no difference between the heights and femur length of individuals with and without scorable teeth. So there is no significant difference in using only the heights of individuals with scorable teeth or using the whole group. For the SPSS output on the t-test on height see Appendix 7. Output for the testing of femora can be found in Appendix 8.

Residuals

As before mentioned, to examine whether body proportions are different for individuals who have suffered periods of physical stress in childhood (manifested as hypoplasias) the residuals for the regression analysis is found as they give information about body proportions. The residuals were found by taking the expected height (calculated from the regression) minus the actual height measured in the grave. Then a t-test was performed to examine the possible difference in body proportions of individuals with and without hypoplasias, which indicates periods of illness or malnutrition.

For both men and women the t-test was performed with a significance level of 5%, and indicated no difference in body proportions of individuals with and without hypoplasias. This makes further calculations regarding body proportions on the two groups unnecessary. See Appendix 9 for the test output.

Discussion

After the data had been collected the first step was to make scatter plots to see if there indeed was a linear tendency, and to search for possible outliers. The scatter plots showed a clear linear tendency between height measured in the grave and the mean value of femur length. T-tests showed that there is no statistical difference between the length of an individual's right and left femur. Then linear regressions were made in terms of height estimation.

The linear regressions are as follows:

$Height_{men} = 2.610 \cdot femur + 44.201$

$Height_{women} = 2.019 \cdot femur + 67.579$

While these linear regressions both had strong linear correlation, and therefore are valid, it is interesting to compare the constants to other investigations of same character. The constants of the linear regressions will be compared to two similar investigations carried out on material from the cemetery of Tirup and Lille Sct. Mikkelsgade. These are also Danish cemeteries from Jutland. These investigations were carried out by Boldsen, and described in *Body Proportions, Population Structure and Height Prediction* [1].

The regression from Boldsen[1] is: $heigth = 2.3182 \cdot femoral\_length + C$. To compare the results from this thesis, to the results of Boldsen, the results are fitted to the regression found by Bolden. The calculations can be found in Appendix 10, and the constants found can be seen in the table below.

Constants calculated from the regression in Boldsen	Males	Females
Ribe	58.11	54.85
Tirup	58.16	54.91
Lille Sct. Mikkelsgade	62.50	59.69
Finns	63.92	59.90
White Americans	65.63	62.03

Table 1: Constants for men and women in Ribe, Tirup, Lille Sct. Mikkelsgade, Finns, and White Americans calculated from the regression from Boldsen (1990).

Table 1 show that the constants from Tirup and Ribe are very similar and Lille Sct. Mikelsgade diverges. This supports a hypothesis that there are two different regressions to calculate height of individuals in medieval populations in Denmark.

The constants from Finns and White Americans from Table 1 are higher than Ribe, Tirup, and Lille Sct. Mikkelsgade. The individuals examined in White Americans are from around year 1950 and the Finns from the early half of the 20th century. Medieval individuals are said to have lower constants than more modern individuals. The results from this examination also support this hypothesis.

The examinations of Tirup include 59 males and 36 females [1] and Lille Sct. Mikkelsgade 31 males and 34 females [17]. Ribe are carried out on a more substantial amount of material, which could suggest that the constants are more precise.

The slopes for the regression from this paper and the slope from Boldsen's regression are shown in Table 2. The slope in this paper for men and women differ from the one in Boldsen, but if the standard deviations from the calculations in this paper are taken into account the slope from each regression are acceptable, since the slope found by Boldsen is included in the intervals.

	Men	Women
Slope Ribe	2.61	2.02
Std. error	0.168	0.262
Calculation with std. error **(**$slope \pm 2 \cdot std.dev.$**)**	[2.274; 2.946]	[1.496; 2.544]
Slope Boldsen	2.3182	2.3182

Table 2: Table showing the slope found in the regression analysis of Ribe with standard errors, and slope from Boldsen for comparison.

The correlation coefficients form the linear regressions showed a strong correlation between the height and femora. While not as strong as with Ribe, the correlation coefficients from Tirup and Lille Sct. Mikkelsgade both show a great association between femur length and height. What is puzzling is that the correlation coefficients for women from all three places are lower than that of men. This could simply be a coincidence but rather indicates that height estimation by femora is more precise for men.

Correlation coefficients	Men	Women
Ribe	0.901	0.777
Tirup [1]	0.800	0.710
Lille Sct. Mikkelsgade [17]	0.874	0.741

Table 3: Correlation coefficients from the linear regressions for Ribe, Tirup, and Lille Sct. Mikkelsgade

Turning to hypoplasias, even though the results in this paper indicates no relation between hypoplasias and body proportion it cannot be concluded that these are not linked. Not all of the factors that cause enamel hypoplasias will affect the morphology, and enamel hypoplasias are weak markers for specific childhood conditions. The amount of individuals without enamel hypoplasias is very modest in both men and women, and this is a weak foundation to conclude that episodes that cause enamel hypoplasias do not affect the adult height of an individual. It could be that either periods of weakness during childhood do not affect body proportions or hypoplasias are not useful as markers of childhood periods of weakness, or simply that not all the episodes which cause enamel hypoplasias affect the adult height. There is also the possibility that children with serious periods of weakness and illness that affected the growth died prior adulthood more often than children with weak periods of illness which did not affect the growth.

Perspectives

The material in this thesis, together with that of Boldsen, indicates that there are different constants in the height/femora relation, for different communities. Further investigations on other communities could give an idea whether it is preferable to make a single equation with all the information or there should be several equations for each area. While this is possible for communities of the medieval times, getting constants for contemporary populations could be problematic, since people tend to travel more, mix, and settle down unaffected by geography. This makes a distinction of groups of communities less clear, and suggests that wide geographic areas only uses one set of constants and these are less precise than the ones found for medieval times.

The knowledge of the relationship between femora and height could be highly usable in forensic medicine when for example a single femur is found, and the investigators have no idea about who the individual is. This simple, but effective method of stature estimation would be helpful in making characteristics of the individual which could lead to identification. It would furthermore be interesting to make similar investigations with other long bones and their association to height. This could potentially allow height estimation from other bones than femur, and enable more precise estimates by looking at several bones. Again, this would be very useful in forensic anthropology.

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Ref Type: Generic

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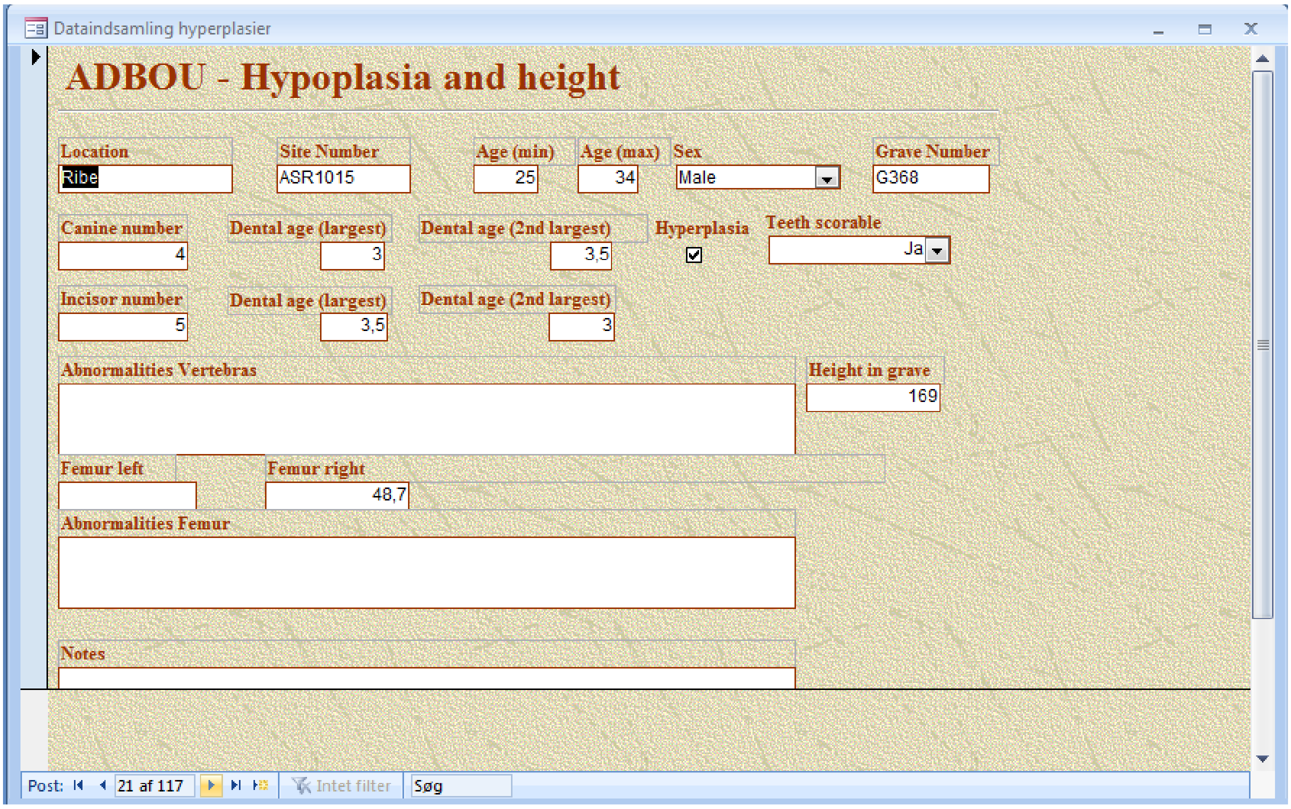
Ref Type: Magazine Article

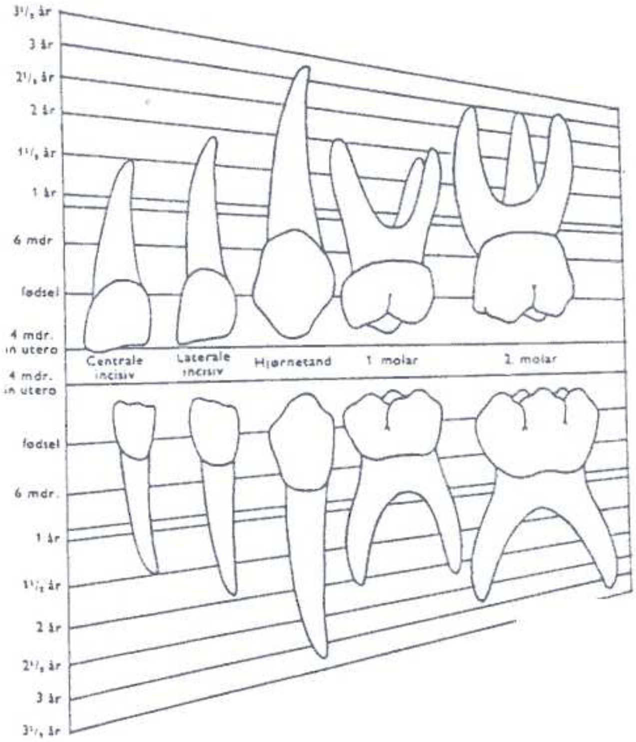
Appendix

Appendix 1



Picture 4: Screen shot of the Microsoft Access database formula, which is used for entering data.

Appendix 2



Picture 5: The chart of teeth which is used to read the age of hypoplasia development. From *Osteological Methods* [10].

Appendix 3

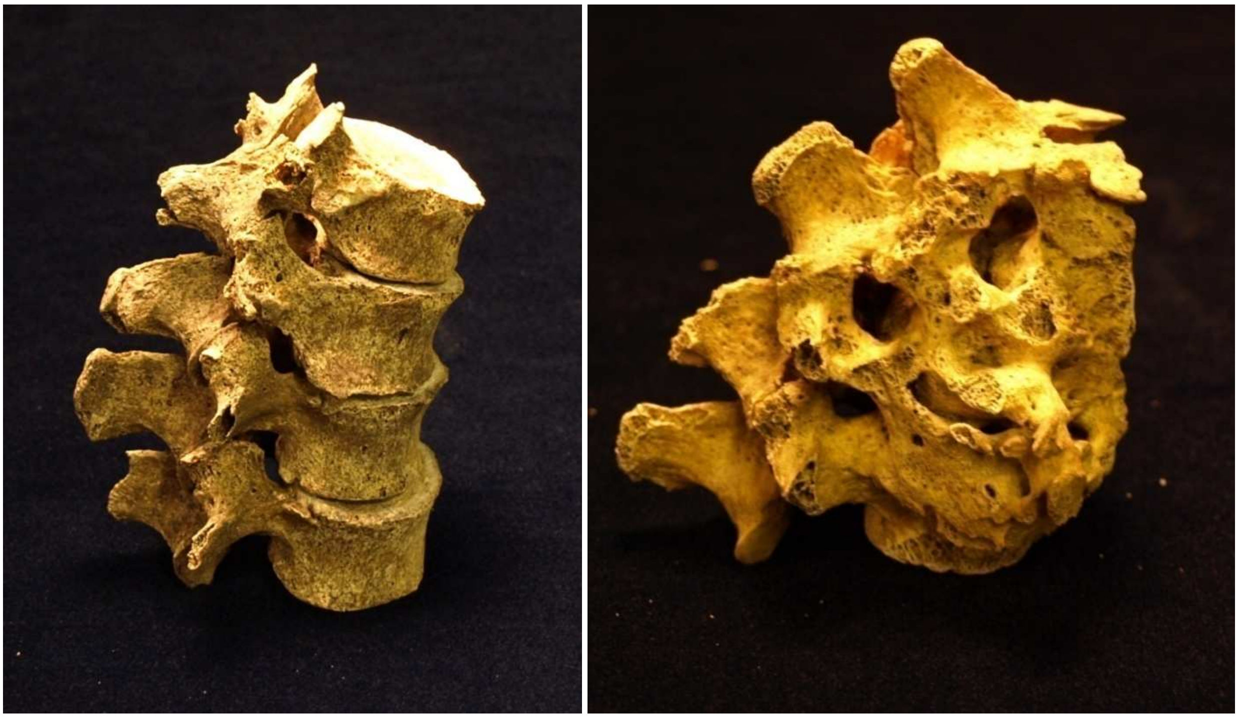
Picture 6: Teeth not suitable for scoring due to wear. Individual OMB9784, G39.

Picture 7: Teeth not suitable for scoring due to wear. Individual OMB9784, G39.

Picture 8: Teeth not suitable for scoring due to tartar. Individual SJG80, G712.

Appendix 4

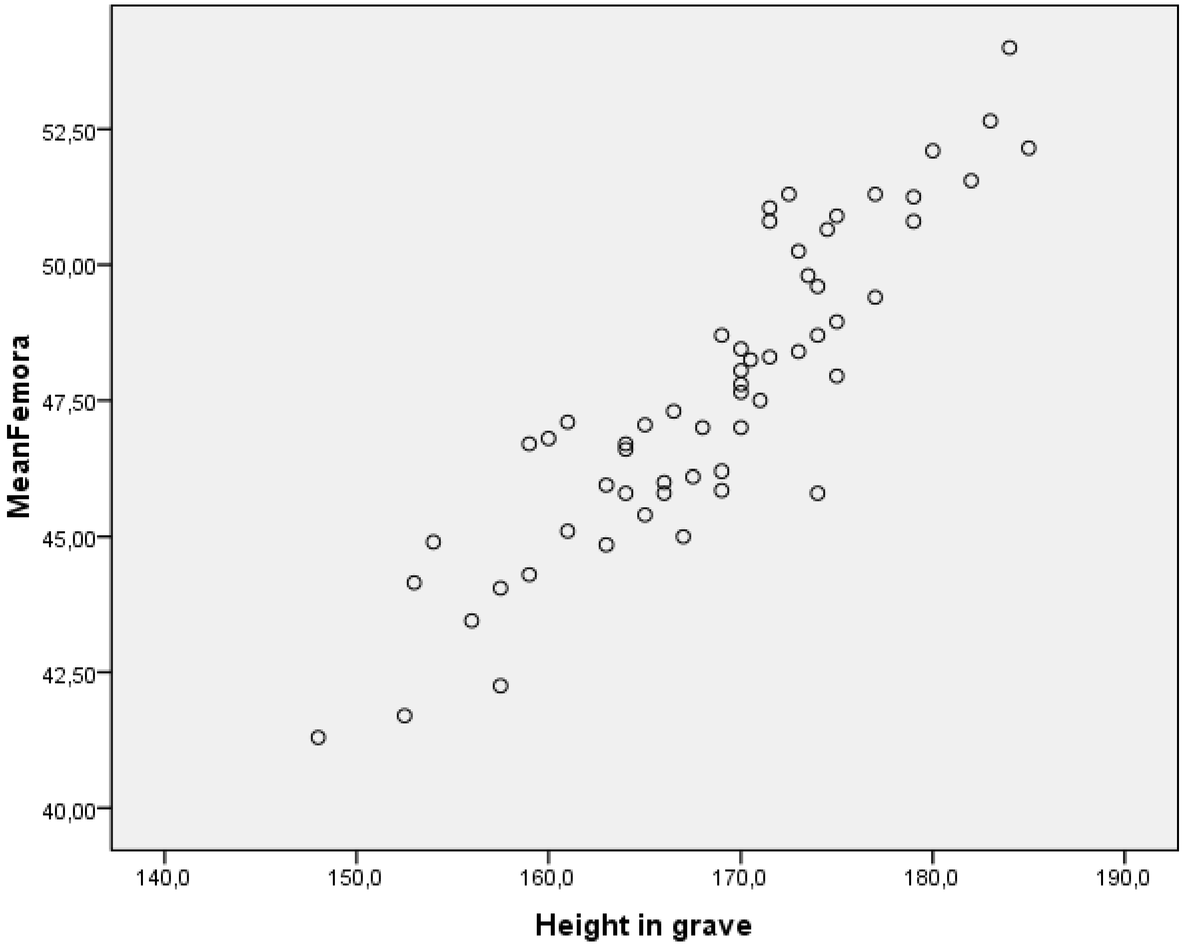
Picture 9: Femur not suitable for measuring due to wear. Individual VKH1201, G204.



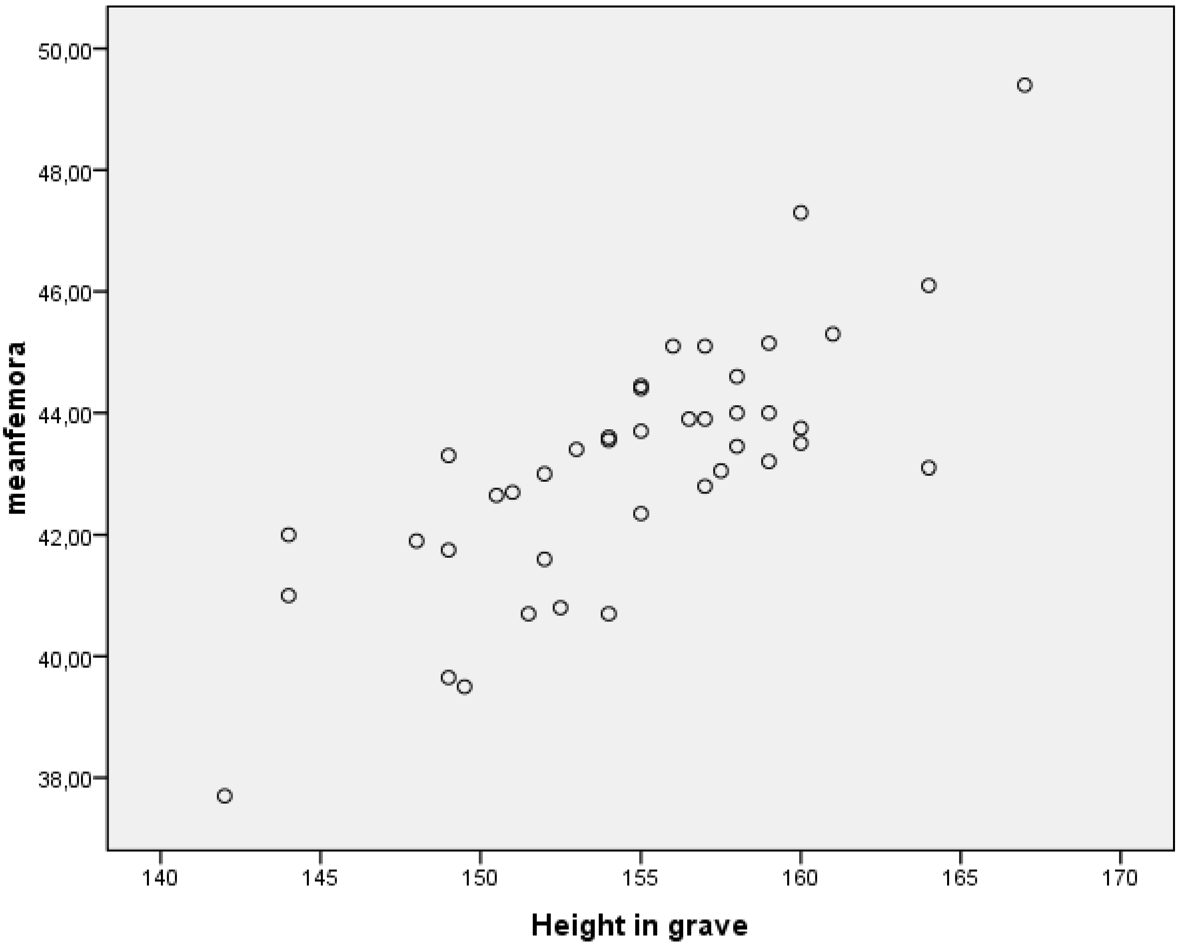
Picture 10: To the left, normal vertebras (SBT81, G25). To the right, fused vertebras which would affect the height measured in the grave (SJG80, G1072).

Appendix 5

Scatter plots:



Picture 11: Scatter plot of height measured in grave and mean length of femur for men. A positive linear tendency can be seen.



Picture 12: Scatter plot of height measured in grave and mean length of femur for women. A positive linear tendency can be seen.

Appendix 6

T-tests examining whether the left and right femora of an individual differ in length. As can be seen from the t-value, this is not the case.

T-test male femora:

T-Test

[DataSet1]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Femur left	47,838	45	2,9973	,4468
	Femur right	47,72	45	2,947	,439

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Femur left & Femur right	45	,978	,000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Femur left - Femur right	,1133	,6192	,0923	-,0727	,2994	1,228	44	,226

T-test female femora:

T-Test

[DataSet1]

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Femur left	42,794	18	1,4449	,3406
	Femur right	42,750	18	1,4694	,3463

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Femur left & Femur right	18	,952	,000

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Femur left - Femur right	,0444	,4540	,1070	-,1813	,2702	,415	17	,683

Appendix 7

T-tests examining whether the height of individuals with and without scorable teeth differ. As can be seen, this is not the case.

T-test height men:

T-Test

[DataSet1]

Group Statistics

	Teeth...	N	Mean	Std. Deviation	Std. Error Mean
Height in grave	0	28	168,107	7,2576	1,3716
	1	39	168,718	8,7010	1,3933

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Height in grave	Equal variances assumed	1,202	,277	-,303	65	,763	-,6108	2,0145	-4,6339	3,4123
	Equal variances not assumed			-,312	63,460	,756	-,6108	1,9551	-4,5172	3,2956

T-test height women:

T-Test

[DataSet1]

Group Statistics

	Teeth...	N	Mean	Std. Deviation	Std. Error Mean
Height in grave	0	26	153,84	5,452	1,069
	1	21	156,00	4,894	1,068

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Height in grave	Equal variances assumed	,000	,996	-1,414	45	,164	-2,162	1,529	-5,241	,918
	Equal variances not assumed			-1,430	44,457	,160	-2,162	1,511	-5,206	,883

Appendix 8

T-tests examining whether the length of femora for individuals in this paper with and without scorable teeth differ. As can be seen this is not the case.

Men:

T-Test

[DataSet1] C:\Users\Metzen\Desktop\Knogle data\Alle mænd.sav

Group Statistics

	Teeth...	N	Mean	Std. Deviation	Std. Error Mean
MeanFemora	0	23	47,1804	2,56239	,53430
	1	35	47,9800	2,99058	,50550

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MeanFemora	Equal variances assumed	,535	,468	-1,053	56	,297	-,79957	,75966	-2,32134	,72221
	Equal variances not assumed			-1,087	52,035	,282	-,79957	,73553	-2,27549	,67636

Women:

T-Test

[DataSet1] C:\Users\Metzen\Desktop\Knogle data\Alle Kvinder.sav

Group Statistics

	Teeth...	N	Mean	Std. Deviation	Std. Error Mean
meanfemora	0	22	43,2136	2,37643	,50666
	1	19	43,1789	1,79020	,41070

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
meanfemora	Equal variances assumed	,820	,371	,052	39	,959	,03469	,66585	-1,31212	1,38150
	Equal variances not assumed			,053	38,348	,958	,03469	,65221	-1,28524	1,35462

Appendix 9

T-tests examining whether the residuals of individuals and without hypoplasias differ. As can be seen from the test, this is not the case.

Group Statistics

	Hyperpl...	N	Mean	Std. Deviation	Std. Error Mean
Residual	0	7	-,4609	3,48873	1,31861
	1	28	,2935	3,83127	,72404

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Residual	Equal variances assumed	,022	,884	-,473	33	,639	-,75445	1,59367	-3,99678	2,48789
	Equal variances not assumed			-,502	9,962	,627	-,75445	1,50432	-4,10801	2,59911

T-tests on residuals for women:

Group Statistics

	Hyperpl...	N	Mean	Std. Deviation	Std. Error Mean
Residual	0	3	1,6919	,30024	,17334
	1	16	,6897	4,12540	1,03135

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Residual	Equal variances assumed	6,729	,019	,411	17	,686	1,00215	2,43892	-4,14352	6,14781
	Equal variances not assumed			,958	15,765	,352	1,00215	1,04582	-1,21757	3,22187

Appendix 10

Fitting the Ribe data to the constant from Boldsen [1]: $C = \overline{H} - \overline{F} \cdot 2.3182$, where $\overline{H}$ is mean height in cm and $\overline{F}$ is mean femur in cm. Mean height and mean femora of the Ribe data are calculated in SPSS.

For men: $C = 168.6cm - 47.66cm \cdot 2.3182 \Leftrightarrow C = 58.1146$

For women: $C = 155.0cm - 43.2cm \cdot 2.3182 \Leftrightarrow C = 54.85376$

Appendix 11

Manual

Manual- ADBOU – Hypoplasias and Femur Length

Registration

The registration of skeletons in this project is stored in Microsoft Office Access. A formula has been created into which the data should be entered. This can be obtained at http://mirror.aidoh.dk/mettewod/wod.zip or by contacting ADBOU. Only adults were the height in grave is known should be included. An adult is defines as an individual were the sphenooccipital synchondrosis (SOS) and all the epiphysis on the long bones have fused. If no data is available for a field, it should be left empty unless indicated otherwise.

This manual should be seen as an supplement to *Osteological Methods* [10].

Form Header

The header is filled out in the exact some way as *Osteological Methods* [10].

Location

See *Osteological Methods* [10].

Site number

See *Osteological Methods* [10].

Age (min) and Age (max)

See *Osteological Methods* [10].

Sex

See *Osteological Methods* [10].

Grave number

See *Osteological Methods* [10].

Teeth scorable

(drop down box) Mandatory. Indicates whether the teeth are scorable or not. A tooth is considered *non scorable* when more than one third of the tooth is worn down. When a tooth is so worn down, there is a possibility that a number of hypoplasias are no longer present and the tooth is not usable

for scoring. The teeth should not be scored if the there is a substantial amount of tartar as this could conceal possible hypoplasias. The examiner is not allowed to remove the tartar.
This has to be filled for every individual to be able to make correct queries in the Microsoft Office Access database.

Hypoplasia

(tick box) Should be ticked if hypoplasias are scored.

Hypoplasias are scored on the upper left canine and left incisor. Linear enamel hypoplasias are defined as a horizontal enamel deficiency visible to the naked eye. Enamel hypoplasias can be difficult to see and the teeth should be examined in both direct and indirect light. Hypoplasias are usually easier to see in indirect light. If the upper left incisor or upper left canine is missing the upper right incisor and upper right canine is used instead.

Canine and incisor number

(text field) The number of hypoplasias visible on the tooth.

Dental age largest and Dental age 2. largest

(text field) The age where the largest and second largest hypoplasias were formed. The age can be read from a chart in *Osteological Methods* [10] section 1.7 Teeth.

Height:

(text field) Height in grave. Measured during excavation using definitions by Boldsen 1984 [8].

Abnormalities Vertebras

(text field) Abnormalities are noted if they could have had an impact on living height. For example a collapsed vertebra gives a false adult height.

Femur left and Femur right

(text field) The maximum length of the right and left femora are measured using a measuring table. The length is entered in the database in centimeters with one decimal.

Abnormalities on femur

(text field) Possible abnormalities on either of the femora that would influence the height measured in the grave should be noted and commented in the database. This could be fractures that have healed abnormally, giving the individual a shorter height than before the fracture and resulting in false adult height. If there are traumas or abnormalities that might affect the adult height it should be taken into account when analyzing the data.
The femora should not be measured if they are destroyed or degraded in a manner that will affect the measurement of the length.

Notes:
(text field) All things of possible interest to self or others are noted here. This could be leprosy, syphilis, FOS, and others. In this way it is easy to find material of interest to different project by searching the database.

Date:
(text field) The date of the registration is noted.

Signature:
(text field) Signature of the person who has collected the data.