MEASURING BODIES OR SOULS AND THE MIRILA CONUNDRUM – A PHYSICAL ANTHROPOLOGY ASSESSMENT BASED ON STATURE ANALYSIS

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In June of 2009 I was approached by dr. Andrej Pleterski from the Scientific Research Center of the Slovenian Academy of Sciences and Arts to do an analysis of the mirila data that have been collected from several sites on the southern Velebit mountain range in Croatia. The reason for this is that the rationale of the mirila is, at present, not clear. These measurements were recorded during an almost two and half century time period (from the 18th to the middle of the 20th century) and vary in length from 52 cm to 210 cm. The following theories are currently used to interpret their function:

1) they correspond to the lengths of human cadavers on their way to burial,
2) they symbolize the dimensions of an individual's soul, and
3) they represent a combination of the two.

Available for analyses were the dimensions of over 250 mirila. What could not be done was to correlate any of these data with either specific individuals of known stature, or even with sex, or age-at-death.

As a forensic anthropologist and bioarchaeologist I frequently collaborate with colleagues from different scientific fields in an attempt to answer various questions. So far, all of these contributions have depended on my analyses of human osteological material recovered from either forensic or archaeological contexts. This is the first time I have been asked to contribute to the solution of a problem that does not involve my examination of human remains from specific sites.

On the assumption that mirila represent an accurate measurement of the lengths of human cadavers on their way to burial, the range of the recorded values (from 52 cm to 210 cm) suggests that both subadults and adults were measured. The first step to solving the problem is, therefore, to calculate a cut-off point that would separate between these two groups. The second is to determine which adult measurements corresponded to males, and which corresponded to females. If these data can be obtained, the mean statures of males and females in the series can be calculated and compared to different contemporary historical populations, as well as to the modern Croatian population. If the mirila values significantly deviate from these values it would be a strong argument against the hypothesis that they represent cadaver lengths. Additionally, tests that analyze whether male and female statures (as represented by the mirila values) are normally distributed in the series can be made. Given the relatively large number of mirila available, a significant departure from a normal distribution would, once again, be a strong argument against the hypothesis that mirila reflected the stature of males and females.

As a more detailed examination of this puzzle shows that it relates to the problem of stature estimation in historical populations I accepted the challenge and devised the following strategy to resolve it.

By now, the estimation of adult human stature from skeletal remains has been researched for over a century (Rollet, 1889; Dwight, 1894; Pearson, 1899). As noted by Lundy (1985), two approaches have been employed in this endeavor: the "anatomical" approach, which involves the summation of superoinferior measurements of contributory skeletal elements to determine stature as directly as possible; and the "mathematical" approach, which involves the extrapolation of living stature from individual skeletal measurements by the utilization of ratios or regression formulae. The former method, most often attributed to Georges Fully (1956), has recently been reexamined in detail by Raxter et al. (2006, 2007). Relatively few studies have, however, employed this approach as regression formulae for long bones (usually the femur and tibia) are much easier to apply. Indeed, a substantial literature has been devoted to the "mathematical" method. Researchers have developed techniques to estimate living statures from a variety of skeletal elements, including the major long bones of the limbs (e.g., Trotter, 1970), crania (e.g., Ryan and Bidmos, 2007), and other whole bones, as well as fragmentary remains (e.g., Simmons et al., 1990). The vast majority of equations have been developed for long bones of the upper and lower limbs to estimate statures of African, Asian and European populations (Trotter and Gleser, 1952, 1958; Fujii, 1960; Allbrook, 1961; Olivier, 1976; Feldesman and Lundy, 1988; De Mendonca, 2000). These studies, as well as studies by numerous other authors have shown that adult stature is both populations specific, and changes through time. To determine, therefore, which mirila correspond to males, and which to females, it is necessary to approximate the stature of males and females from a reference collection of temporally congruent Croatian historical populations. To this end the Osteological collection of the Croatian Academy of Sciences and Arts was checked for the presence of 18th to 19th century historical populations.

The collection, founded in 1993 currently contains slightly more than 5500 skeletons from 37 archaeological sites in Croatia that cover the time period between approximately 9000 BC to the 19th century AD. Two archaeological sites fulfilling the necessary qualifications were found: Sisak, and Rijeka. Bicondylar lengths of left femurs from well preserved male and female skeletons in whom sex could be unequivocally assigned based on pelvic (Bass 1987), and cranial morphology (Krogman and Işcan, 1986), were measured according to the criteria of Martin (Martin, 1928, FBL #2). These measurements were used to calculate adult stature using regression formulae for the femur calculated by Pearson (1899). Pearson's formulae were used because a recent study of modern Croatian adult stature estimation based on radiographic measurements of cadaver long bone lengths (Petrovečki, 2001) showed that these formulae were most applicable to Croatian populations.

Once adult statures are successfully calculated, a discriminant function analysis can be performed on them to determine whether stature can be utilized to differentiate between males and females. Sex determination is amenable to discriminant function analysis based on the assumption that the two sexes will produce a bimodal curve. Numerous researchers, including researchers of modern and archaeological populations from Croatia were able to obtain discriminant function accuracy rates of 92.2% to 94.4% using various dimensions of the femur (Šlaus, 1997; Šlaus et. al., 2003), and tibia (Šlaus and Tomičić, 2005). As both of these long bones are highly correlated with adult stature it is reasonable to expect that discriminant function analysis of stature will also result in a high accuracy rate.

To separate between subadults and adults mean femoral lengths of modern subadults measured by Anderson et al. (1964) are used to (once again using Pearson's regression formula) calculate the cut-off point for subadult stature.

8.1 MATERIALS AND METHODS

A total of 350 mirila measurements from two sites: Vukići (n=266), and Kruščica-Korita (n=84) were available for analysis. The mirila were categorized into one of three groups – mirila taken predominantly during the 18th century (category 1), those taken predominantly during the 19th century (category 2), and mirila taken during the 20th century (category 3). Because there is some ethnographic evidence that mirila taken during the 20th century may represent coffin lengths it was decided to leave these measurements out. The total number of measurements in this analysis is therefore 328, with Vukići contributing 256 and Kruščica-Korita 72 measurements.

The two Croatian historical populations used to approximate the stature of males and females based on femoral lengths are Sisak and Rijeka. In geographic terms both sites are relatively near to Kruščica-Korita and Vukići. Rijeka is approximately 160 km north-west of the two analyzed sites, while Sisak is approximately 130 km north-east of them. Both sites are also temporally congruent. The osteological material from Rijeka was recovered during archaeological excavations on the Rijeka – Trg pul vele crikve site carried out from 2008 to 2009. This is a multicomponent site that, among other features, contained a late historic cemetery. A total of 115 skeletons were recovered during the excavation. Unfortunately only 38 skeletons (17 male and 21 female) in which sex could be unambiguously assigned based on pelvic and cranial morphology had sufficiently preserved femora. Archaeological and historical sources indicate that the Rijeka cemetery was used from the 17th to the 19th centuries (Višnjić, personal communication).

The osteological material from Sisak was recovered during archaeological excavations of the Square of Ban Josip Jelačić in Sisak carried from 1997 to 2001. Excavations revealed the presence of the Late Historic town cemetery that was located adjacent to the church of the Assumption of the Holy Cross. The cemetery was in use from the 17th to the 19th century. A total of 147 graves were excavated (Lolić, 2001). Slightly less than a third (n=57 of which 33 were males, and 24 were females) contained skeletons with sufficiently preserved elements to measure the femora and accurately determine sex. The total number of skeletons available for discriminant function sexing based on adult stature was therefore 95.

Pearson's regression formulae for estimating stature from the dimensions of the femur were utilized to calculate the stature of males and females in this sample. The formula for estimating male stature is:

male stature = 81.306 + 1.88 x length of femur;

the formula for estimating female stature is:

female stature = 72.844 + 1.945 x length of femur

As previously noted, Pearson's regression formulae were used because a recent study (Petrovečki, 2001) of modern Croatian adult stature estimation based on radiographic measurements of cadaver long bone lengths demonstrated that these formulae had the best predictive values for the modern Croatian population. Several regression formulae including those developed by Telkka (1950), Trotter and Gleser (1958), Jantz (1992) and De Mendonca (2000) were also tested, but the margin of error in all of these was greater than the one noted for Pearson's regression formulae.

Pearson's regression formulae for the femur were also used to determine the cut-off point between subadults and adults. Stature estimates for children are not usually attempted in bioarchaeology because in life their standing height is derived from both the diaphyses and epiphyses of long bones, joined by a cartilage growth plate. Our inability to assess the contribution of the cartilaginous growth plate to length and standing height (because it varies in thickness at different times of the child's development, as well as between individuals) prevents accurate estimates of stature in skeletonized remains. This having been said, some data are available that allow for the approximate thickness of the growth cartilage and epiphysis to be calculated. Maresh (1955) collected both diaphyseal and long-bone length data for male and female French Canadian White children. His data overlaps in the 10 to12-year age groups for boys and girls revealing that femoral epiphyses account for 3.8% of bone length in boys and 4.6% of bone length in girls. Fortunately this analysis is not concerned with accurate stature determination of subadults of known age based on the dimension of their long bones. What I am looking for is a simple cut-off point that separates subadults from adults in the Vukići and Kruščica-Korita series. In bioarhaeological studies subadults are usually denoted as individuals younger than 15 years. The reason for this is that the three elements that comprise the adult innominate: the ilium, ischium and pubis, usually fuse by 15 years allowing accurate determination of sex. However, as this analysis deals with the stature of individuals that lived during the 18th and 19th centuries (and all of our reliable published data on subadult femur lengths comes from modern populations) it is necessary to take into account factors such as secular growth, and the significantly improved nutrition of subadults living during the 20th century. Therefore, to be absolutely sure that the analysis differentiates between subadults and adults - and not between subadults along with smallish adults, and taller adults, the cut-off point between subadults and adults was calculated using the mean length of the subadult female femur aged 12 years minus one standard deviation as measured by Anderson et al. (1964).

8.2 RESULTS

The descriptive statistics for the mirila are presented in Table 1. As is evident from this table the mean lengths of the mirila in Krušcica-Korita (mean length = 155.24; sd = 37.03; n = 72), are considerably greater than those recorded in Vukići (mean length = 138.35; sd = 39.96; n = 256). Analysis of variance indicates that this difference is statistically significant (F = 10.356, P = 0.001).

	Vukići 18th century (n=119)	Vukići 19th century (n=137)	Vukići Total (n=256)	Kruščica-Korita 18th century (n=22)	Kruščica-Korita 19th century (n=50)	Krušcica-Korita Total (n=72)
Descriptive statistics						
Mean	135.76	140.59	138.35	166.55	150.26	155.24
Median	140.00	154.00	146.00	166.00	164.00	165.00
Std. Deviation	38.78	40.97	39.96	19.88	41.65	37.03
Range	153	156	156	68	146	146
Minimum	54	52	52	138	64	64
Maximum	207	208	208	206	210	210

Table 1. Descriptive statistics for the mirila by site and category

Table 2 shows the descriptive statistics of adult statures for both sexes in the reference Croatian historical series. These statures were calculated from the bicondylar lengths of the left femurs using Pearson's regression formulae for the femur for males and females. The index of dimorphism is greater than 100 indicating that males in the series were, as expected, higher than females. The F-ratio indicates that the difference is significant (P < 0.001) while the standard deviations indicate that males exhibited more variation than females. This result indicates strong sexual dimorphism in the analyzed sample and presupposes that adult stature is useful in differentiating between the sexes.

	Males			Females			Sexual dimorphism	
Variable	N	Mean	Std. Dev.	N	Mean	Std. Dev.	Index[2]	F[3]
Adult stature	50	168.19	4.07	45	155.31	2.90	108.29	308.79

[1] Stature was calculated with Pearson's regression formulae for estimating stature from the dimension of the femur
[2] Index = male mean/female mean x 100
[3] Significant at P < 0.001

Table 2. Sexual dimorphism and unifactorial statistics of adult stature[1] in the temporally congruent skeletal series from Sisak and Rijeka

Once the existence of a strong sexual dimorphism was determined, a discriminant function was generated. The unstandardized discriminant function coefficient, sectioning point, and cut-off point are presented in Table 3. Unstandardized discriminant function coefficients are used for calculating

Variable	Adult stature
Unstandardized coeff.	0.280
Constant	-45.428
Sectioning point	-0.095
Cut-off point	males > 162.75 > females

Table 3. The unstandardized 0 discriminant function coefficient, constant, sectioning point, and cut-off point calculated by the discriminant function analysis of stature in the Rijeka and Sisak skeletal series

discriminant function scores from the raw data. A discriminant score is obtained by multiplying the variable (adult stature) with the unstandardized coefficient and then adding the constant. If the score is greater than the sectioning point the individual is considered male, while a lower score indicates a female. An alternative, and simpler, approach in discriminant functions where only one variable is used is to compare the dimension of the analyzed specimen to a cut-off point. The cut-off point is in this case the simple average of the means for each sex or in this case 162.75 cm. A value higher than this indicates a male, a lower value indicates a female.

Reclassification of the cases used to develop the function shows that the overall accuracy for both sexes is a very high 97.9% (Table 4). A slightly lower accuracy was achieved for males (96.0% or 48/50) while all 45 females in the series were accurately sexed based on their stature as approximated with Pearson's regression formula.

		Males		**Females**		
Variable	N	%	N	%	N	Average
Adult stature	95	96.0	48/50	100.0	45/45	97.9%

Table 4. Sexing accuracy for the discriminant function

As the cut-off point between male and female stature in the temporally congruent skeletal series from Croatia is 162.75 cm, all mirila equal to, or longer, than 164.0 cm are considered to have been males. As previously noted, to differentiate between subadult and adult mirila, the mean length of the modern subadult female femur aged 12 years minus one standard deviation was used. According to the results of Anderson et al. (1964) this gives a femoral length of 38.23 cm resulting in a stature of 147.1 cm. The cut-off point between subadults and adults in the series is therefore determined at 148.0 cm.

All together this means that all mirila smaller than 148.0 cm are judged to have been subadults, mirila between 149.0 and 163.0 cm are considered to have been females, and all those higher than 164.0 cm are deemed to have been males.

	Vukići 18th century (n=119)		Vukići 19th century (n=137)		Vukići Total (n=256)		Kruščica-Korita 18th century (n=22)		Kruščica-Korita 19th century (n=50)		Krušcica-Korita Total (n=72)	
Sex distribution	N	%	N	%	N	%	N	%	N	%	N	%
Males	32	26.9	48	35.0	80	31.2	12	54.5	25	50.0	37	51.4
Females	17	14.3	26	19.0	43	16.8	6	27.3	7	14.0	13	18.0
Subadults	70	58.8	63	46.0	133	52.0	4	18.2	18	36.0	22	30.6
Total	119	100.0	137	100.0	256	100.0	22	100.0	50	100.0	72	100.0

Table 5. The sex distributions in the Vukići and Kruščica-Korita series

Applying these criteria to the Vukići and Kruščica-Korita mirila produces the following sex distributions (Table 5). Slightly more than half (52.0%) of the Vukići series were subadults while males in the sample (80/256 or 31.2%) outnumber females (43/256 or 16.8%) by a ratio of 1.86 : 1.00. In the Kruščica-Korita series males (37/72 or 51.4%) are most frequent, followed by subadults (22/72 or 30.6%), and females (13/72 or 18.0%). The male to female ratio in this series is 2.85 : 1.00.

An additional point of interest concerns the distribution of subadult mirila values. As previously mentioned, subadults comprise a large proportion of both the Krušcica-Korita (22/72 or 30.6%) and Vukići (133/256 or 52.0%) series. On the assumption that the mirila represent the lengths of

	Vukići 18th century (n=49)	Vukići 19th century (n=74)	Vukići Total (n=123)	Kruščica-Korita 18th century (n=18)	Kruščica-Korita 19th century (n=32)	Kruscica-Korita Total (n=50)
Male						
N	32	48	80	12	25	37
Mean	182.03	181.02	181.42	180.66	184.12	183.00
Median	180.00	180.00	180.00	175.00	182.00	179.00
Std. Dev.	12.90	11.83	12.20	15.79	13.83	14.37
Range	43.00	44.00	44.00	41.00	45.00	45.00
Minimum	164.00	164.00	164.00	165.00	165.00	165.00
Maximum	207.00	208.00	208.00	206.00	210.00	210.00
Skewness	0.424	0.626	0.533	0.999	0.555	0.639
Female						
N	17	26	43	6	7	13
Mean	155.35	157.11	156.41	153.33	155.85	154.69
Median	155.00	157.00	157.00	153.00	155.00	155.00
Std. Dev.	4.52	4.36	4.46	2.25	5.27	4.21
Range	13.00	13.00	13.00	5.00	14.00	14.00
Minimum	150.00	150.00	150.00	151.00	149.00	149.00
Maximum	163.00	163.00	163.00	156.00	163.00	163.00
Skewness	0.202	-0.191	-0.047	0.012	0.570	1.101

Table 6. The descriptive statistics for male and female mirila by site and category

cadavers being taken to burial this would suggest a high subadult mortality ratio. By itself, this is not problematic. What is, however, interesting is that the majority of the subadult mirila are longer than 100.0 cm. According to modern global standards the average height of a three years old child is approximately 100.0 cm. Applying this criteria to the Vukići and Kruščica-Korita series results is a subadult age distribution in which only 6/22 or 27.3% of subadults in Kruščica-Korita, and 55/133 or 41.3% of subadults in Vukići died before reaching three years of age.

The descriptive statistics for male and female mirila in Vukići and Kruščica-Korita are presented in Table 6. As is evident from this table male mirila values are consistently, in all subcategories, at the level of complete Vukići and Kruščica-Korita samples, as well as the level of the complete analyzed sample - higher than female values. Of interest is the fact that the, considerably smaller, Kruščica-Korita series (n= 50) exhibits evidence of secular growth – average male mirila values increase from the 18th to the 19th century by 3.45 cm (from 180.67 cm to 184.12 cm), and average female mirila values increase by 2.53cm (from 153.33 cm to 155.86 cm), while the larger Vukići series (n= 123) exhibits a considerably smaller increase of 1.76 cm in average female mirila values (from 155.35 cm in the 18th century to 157.11 cm in the 19th century), while average male mirila values decrease by 1.01 cm (from 182.03 in the 18th century to 181.02 in the 19th century).

Kolmogorov-Smirnov tests of normality (Table 7) indicate that in the total Kruščica-Korita series neither male nor female mirila values have a normal distribution (Kolmogorov-Smirnov statistic = 0.147; P = 0.041 for males, and Kolmogorov-Smirnov statistic = 0.240; P = 0.039 for females). In the total Vukići series male mirila values, once again, do not exhibit a normal distribution (Kolmogorov-Smirnov statistic = 0.130; P = 0.002), while female values do (Kolmogorov-Smirnov statistic = 0.120; P = 0.127). The same trend is noted at the level of the compete analyzed series - female mirila values exhibit a normal distribution (Kolmogorov-Smirnov statistic = 0.104; P = 0.200), while male do not (Kolmogorov-Smirnov statistic = 0.107; P = 0.002).

	Kolmogorov-Smirnov		
	Statistic	df	Significance
Kruščica-Korita			
Male	0.147	37	0.041
Female	0.240	13	0.039
Vukići			
Male	0.130	80	0.002
Female	0.120	43	0.127
Total mirila sample			
Male	0.107	117	0.002
Female	0.104	56	0.200

Table 7. Kolmogorov-Smirnov tests of normality for Krušcica-Korita, Vukići, and the total mirila sample

DISCUSSION 8.3

Our perception of our own or another individual's stature is influenced by numerous factors. Bias in self-reporting of stature has previously been documented (Willey and Falsetti, 1991), as have problems in the perception of stature by others. For instance, Komar (2003) reported that less than a third (29.4%) of the positively identified individuals recovered from mass graves in the Srebrenica region in Bosnia and Herzegovina had a height that fell within the estimated ranges provided by close relatives. Similarly, the identification team commissioned by the Croatian Government to identify victims recovered from individual and mass graves related to the 1991 War in Croatia used a large margin of error (10 cm) for stature estimates of missing individuals provided by close relatives (Šlaus et al., 2007).

Analyses described in the preceding part of the paper were undertaken to determine whether mirila values correspond to the lengths of human cadavers that were being transported to burial. At first glance that is a reasonable assumption. The mirila are clustered around a road in a manner reminiscent of a cemetery. Some mirila are grouped together and appear to represent family units. Additionally, the morphology of some of the mirila is uncannily similar to that of an osteometric board – an instrument used to measure the lengths of long bones in anthropological studies.

The results of the analyses carried out in this investigation, however, strongly suggest that mirila *do not* correspond to cadaver lengths. This assertion is based on the following five arguments.

The first concerns the demographic profiles of the Vukići and Kruščica-Korita series determined through the cut-off points calculated by discriminant function analysis of male and female stature in the temporally congruent historical populations of Rijeka and Sisak. An exceptional feature of both the Vukići and Kruščica-Korita series is their markedly uneven male to female ratio. In the Vukići series this ratio is 1.86 : 1.00, and in the Kruščica-Korita series it is an even larger 2.85 : 1.00. The total male to female ratio, therefore, in both series is 2.10 : 1.00.

In Croatian archaeological and historical cemetery series the male to female ratio is usually close to 1.00 : 1.00. For instance, the male to female ratio in Rijeka is 1.31 : 1.00, while in the Sisak series it is 1.16 : 1.00. Comparisons with other, larger composite series from Croatia support this trend. The male to female ratio in a large (n= 201) historic period series from continental Croatia is 1.04 : 1.00 (Šlaus, 2002), in an equally large (n= 175) Late medieval series from continental Croatia the ratio is 0.97 : 1.00 (Šlaus, 2002), and in an even larger (n= 331) Early medieval series from Croatia's eastern Adriatic coast the ratio is 1.04 : 1.00 (Šlaus 2006). The absence of females in the Vukići series– where they account for only 16.8% of the total sample, and in the Kruščica-Korita series - where they account for just 18.0% of the total sample is, therefore both exceptional and baffling.

A second important demographic inconsistency concerns the age distribution of subadults in the two series. As previously noted, subadults comprise a large fraction of both series: in Kruščica-Korita they account for 30.6% of the total sample, while in Vukići they represent more than half

(52.0%) of the total sample. By today's standards such frequencies of subadult mortality appear staggeringly high. However, and unfortunately, if anything these values probably underestimate the real mortality of subadults in pre-industrial populations. These populations had a limited knowledge of the dangers that lurk in the microscopic world of microbes, bacteria and viruses, and even more importantly had limited access to adequate nutrition and no access to antibiotics. Consequently subadult mortality, particularly during the first three years of life, was extremely high. In some archaeological and historical series children younger than one year account for up to a third of the total sample (Coale and Demeny, 1966; Ledermann, 1969; Acsadi and Nemeskeri, 1970). This is the problem with the Vukići and Kruščica-Korita series. While general subadult mortality in these series appears to have been high, the mortality of children younger than three years of age is unexplainably low. Employing a fairly conservative criterion that confines subadults younger than three years of age to a stature less than 100.0 cm results in a subadult age distribution in which only 39.3% of the subadult sample or 18.6% of the complete sample died before reaching three years of age. This suggests a highly unlikely scenario in which mortality rates from four to twelve years were higher than those during the first three years.

Infant mortality figures for many past populations are uncertain, but it is estimated (Orme, 2001) that in sixteenth-century England around 27% of children died before the age of one year. Lewis (2007) summarized child mortality patterns derived from archaeological skeletal collections in the published literature. Despite the almost ubiquitous under-representation of infants (individuals aged between birth and the first year) in archaeologically derived skeletal series in the 42 samples (containing 9658 individuals) included in this review, the percentage of subadults who died between birth and the first year was 29.5%, while the percentage of subadults who died between one and four years was 27.5% thus giving a total child mortality rate of 57.0% for the period between birth to four years of age. The considerably lower (39.3%) mortality rate of subadults aged between birth to three years in the Kruščica-Korita, and Vukići series is, therefore, hard to explain.

Three inconsistencies are also noted when the actual mirila values are analyzed. The first concerns the absence of secular growth in males from the Vukići series coupled with the simultaneous presence of secular growth in both males and females from Kruščica-Korita, and females from Vukići.

Secular changes in growth and maturation have been well documented in various world populations, with secular increase especially noticeable in the developed countries. For instance, Ohyama et al. (1987) analyzed secular growth in a sample of 738 students from Kyushu in Japan from 1961 to 1981 and noted an increase in means of standing height, leg length, and ratio of leg length to standing height. Loesch et al. (2000) compared data on stature and body weight obtained during 1992-1993 from 1804 Melbourne school students aged 5 to 17 years, with historical data collected from white Australians during the last 100 years and noted a secular increase in adult stature with the rate of increase varying between 0.4 and 2.1 cm/decade in males, and 0.01 and 1.6 cm/decade in females. In contrast to these results, Pretty et al. (1998) analyzed the adult stature of Aboriginal South Australians from prehistoric to recent times and noted no significant increase in height in either sex.

No systematic analyses of secular changes in Croats have, so far, been undertaken but some tentative approximations can be made. The oldest available data on adult Croat stature is available from the first Croatian manual for forensic medicine published in 1889 by dr. Niko Selak. Among other data Selak (1889) gives the mean cadaver lengths of adult males (168.5 cm, range from 157.0 – 180.0 cm), and females (156.5 cm, range from 153.0 – 166.0 cm) without, unfortunately, giving the number of cadavers these values were calculated from or their provenance. As a matter of interest, the values themselves are (taking into account secular growth as these values were collected presumably during the end of the 19th century) very similar to the cut-off points calculated from the Rijeka and Sisak series to differentiate between male and female mirila (female range from 149.0 – 163.0 cm, male range 164.0 cm and higher).

Data on modern Croat stature is supplied by Petrovečki (2001) and Mustajbegović (1992). Petrovečki (2001) analyzed 41 modern cadavers and calculated that the mean cadaver length of males in Croatia is 173.6 cm, and that of females is 162.4 cm. Based on the analysis of the stature of

4844 individuals living in rural and urban communities in Croatia Mustajbegović (1992) calculated the mean height of urban males at 174.0 cm, rural males at 173.3 cm, urban females at 161.9 cm, and rural females at 161.5 cm.

Comparing these data to Selak's suggests a secular increase in stature of 0.54 cm/decade in females, and 0.46 cm/decade in males. As these data indicate a noticeable secular increase in stature for both males and females, and the same trend is noted in males and females from Kruščica-Korita, along with females from Vukići, it is unclear why Vukići males exhibit a decrease in height of 1.01 cm during the same time period.

A further inconsistency related to the mirila values concerns their distribution. A normal or "Gaussian" distribution is a continuous probability distribution that describes data that cluster around the mean. The graph of the associated probability density function is bell-shaped, with a peak at the mean, and is known as the Gaussian function or bell curve. Human stature, particularly if the sample is large enough, usually exhibits a normal distribution. A point in fact is that "Wikipedia" the free internet encyclopedia, currently uses adult stature of males in the USA to demonstrate what a normal distribution is.

Summary statistics of the Vukići and Kruščica-Korita mirila data that include measures of central tendency such as the mean and median, measures of dispersion such as the standard deviation, and measures of distribution such as skewness and kurtosis, as well as Kolmogorov-Smirnov tests of normality, show that in the total Kruščica-Korita series neither male (n = 37) nor female (n = 13) mirila values have a normal distribution. This can perhaps be explained by the fact that these are, by far, the smallest of the analyzed samples. In the Vukići series female mirila (n = 43) have a normal distribution, while male (n = 80) do not. This is harder to explain as is the fact that at the level of the total mirila sample from both sites female values (n = 56) once again exhibit a normal distribution, while male (n = 117) do not. These results are, therefore, consistent with the theory that factors other than human stature were being incorporated into mirila values.

Finally, comparing mirila values with the calculated statures of males and females from other temporally congruent populations, as well as with the stature of modern Croats strongly suggests that mirila are not an accurate representation of the stature of the past inhabitants of Vukići and Kruščica-Korita.

The mean value of male mirila in the total Kruščica-Korita and Vukići series is 181.9 cm (s.d. = 12.9 cm), the mean value of female mirila is 156.0 cm (s.d. = 4.4 cm). By itself, this is a fascinating fact that suggests that the average difference in height between a man and a woman in these communities was 25.9 cm. To put this into context, the average difference between modern Croat males and females is 12.1 cm, while the difference between mean male and female stature in the Rijeka and Sisak historical series was 12.9 cm.

The mean male stature in the temporally congruent historical series from Rijeka and Sisak is 168.2 cm (s.d. = 4.1 cm), while the mean female stature is 155.3 cm (s.d. = 2.9 cm). This suggests that males in Vukići and Kruščica-Korita were, on average, 13.7 cm taller than those in Rijeka and Sisak. A Kruskal-Wallis test indicates this difference is significant ($\chi^2 = 48.20$, df = 1, $P < 0.001$). At the same time, the difference between female statures is almost negligible. Females in Vukići and Kruščica-Korita were, on average, just 0.7 cm taller than those in Rijeka and Sisak and a Kruskal-Wallis test indicates this difference is, as expected, not significant ($\chi^2 = 0.48$, df = 1, $P = 0.49$).

Comparing mirila values with the stature of modern Croats is also illuminating. The average male stature in Croatia today is 174.0 cm while the average female stature is 161.9 cm. This means that males in Vukići and Kruščica-Korita were on average 7.9 cm taller than modern Croats, while females were 5.9 cm shorter. These values are simply not realistic.

To summarize, the preponderance of the collected evidence suggests that mirila represent actual cadaver dimensions of the 18th and 19th century inhabitants of Vukići and Kruščica-Korita only if these people: a) lived in communities in which males outnumbered females by a margin of more than 2 : 1, b) if subadult mortality rates in these communities were different from all other published archaeological and historical series with relatively low mortality rates from birth to the third year, and high mortality rates during the period between the fourth and twelfth year, c) if males in Vukići exhibit not only an absence of the secular growth noted both in the females who lived with them, and in males and female from Kruščica-Korita but, in fact, decreased in height from the 18th to the 19th century, d) if males from Vukići and Kruščica-Korita did not have a normal distribution of height while females did, and additionally were on average almost 26 cm taller than the women in their communities, and e) if males in the 18th and 19th century Vukići and Kruščica-Korita communities were significantly taller than their contemporaries in Rijeka and Sisak, and modern Croats.

If any of these assumptions are not true - and I can think of no valid reason why they should be - than mirila measured something other than simple cadaver lengths.