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Stature in Archeological Samples From Central Italy: Methodological Issues and Diachronic Changes

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ABSTRACT Stature reconstructions from skeletal remains are usually obtained through regression equations based on the relationship between height and limb bone length. Different equations have been employed to reconstruct stature in skeletal samples, but this is the first study to provide a systematic analysis of the reliability of the different methods for Italian historical samples. Aims of this article are: 1) to analyze the reliability of different regression methods to estimate stature for populations living in Central Italy from the Iron Age to Medieval times; 2) to search for trends in stature over this time period by applying the most reliable regression method. Long bone measurements were collected from 1,021 individuals (560 males, 461 females), from 66 archeological sites for males and 54 for females. Three time periods were identified: Iron Age, Roman period, and Medieval period. To determine the most appropriate equation to reconstruct stature the Delta parameter of Gini (Memorie di metodologia statistica. Milano: Giuffre A. 1939), in which stature estimates derived from different limb bones are compared, was employed. The equations proposed by Pearson (Philos Trans R Soc London 192 (1899) 169–244) and Trotter and Gleser for Afro-Americans (Am J Phys Anthropol 10 (1952) 463–514; Am J Phys Anthropol 47 (1977) 355–356) provided the most consistent estimates when applied to our sample. We then used the equation by Pearson for further analyses. Results indicate a reduction in stature in the transition from the Iron Age to the Roman period, and a subsequent increase in the transition from the Roman period to the Medieval period. Changes of limb lengths over time were more pronounced in the distal than in the proximal elements in both limbs. Am J Phys Anthropol 135:284–292, 2008. ©2007 Wiley-Liss, Inc.

From an historical point of view, stature was of interest to anthropologists because it was an important feature to define a morphological "type" and because it visualizes the human skeletal sample under study. Today, interest in the study of stature lies in its high eco-sensibility. Although stature has a genetic base, the final phenotype is significantly influenced by socioeconomic and environmental factors. The study of stature and its temporal changes can provide important contributions to the reconstruction of life and health conditions in past and present populations. It is of broad use in the analysis of human-environment relationships in different social, economic, and cultural contexts (Steckel, 1995; Larsen, 2002).

Some methodological problems, however, still limit our knowledge of body height and trends over time in past populations. These methodological issues are related to practical difficulties in reconstructing stature from skeletal remains. The anatomical method proposed by Fully and Pineau (1960) provides the most reliable results but it requires virtually complete skeletons, unfortunately a requirement that is rarely fulfilled in archeological samples. Alternatively, to derive stature from skeletal remains, long bone lengths are transformed into stature estimates by means of regression equations based on the biometric relationships between height and limb bone lengths. These regression equations provide stature estimates with a certain margin of error that, as we will see, can be reduced through a careful selection of the regression method used.

Formicola and colleagues discussed in a number of articles, on Italian prehistoric populations, changes in stature over time and space, and the relative methodological problems (Formicola, 1983, 1993; Formicola and Franceschi, 1996; Formicola and Giannecchini, 1999). A comprehensive review of the literature shows that in reconstructions of stature in Italian archeological skeletal samples (from Iron Age to Medieval period) the regression equations of Olivier et al. (1978), Trotter and Gleser for Whites (1952, 1977), Pearson (1899), and the tables of Manouvrier (1893) were used the most. Authors however, rarely justify their choices and no study has yet provided a systematic analysis of the reliability of these regression equations for Italian historical samples.

When assembling a synthesis of changes in height in Italy over historical and protohistorical times, there are difficulties largely due to the problems of comparing data from different analyses, performed with different regression equations. Borgognini-Tarli and Repetto (1986) discussed temporal changes in height in the

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TABLE 1. Archeological materials examined

Region	Date	Archeological site	Males	Females	Location[a]
Iron Age					
Campania	9th–4th B.C.	Pontecagnano	49	53	UniFi
Emilia	5th B.C.	Casteldebole	0	1	UniBo
Emilia	4th–5th B.C.	Ceretolo	26	9	UniBo
Emilia	6th–4th B.C.	Giardini Margherita	2	0	UniBo
Emilia	6th–4th B.C.	Montericco	5	4	UniBo
Emilia	5th–4th B.C.	San Martino in Gattara	1	0	UniBo
Lazio	9th B.C.	Castiglione	8	20	MPE
Lazio	9th–7th B.C.	Osteria dell'Osa	34	31	L
Lazio	6th–2nd B.C.	Tarquinia	11	11	UniPi
Lazio	5th B.C.	San Giovenale	1	0	L
Marche	6th–3rd B.C.	Camerano	25	13	SAT
Marche	8th–7th B.C.	Matelica	7	2	SAT
Marche	8th B.C.	Novilara	8	5	UniBo
Molise	6th–4th B.C.	Pozzilli	19	15	UniBo
Toscana	5th B.C.	Cerretelli-Chianciano	1	1	SAT
Toscana	2nd B.C.	Chianni	1	0	L
Toscana		Chiusi Foro Boario	1	0	SAT
Toscana		Chiusi San Vincenzo	1	0	SAT
Toscana		Chiusi	1	0	MSN
Toscana		Le Porciglie	1	0	SAT
Toscana	7th–6th B.C.	Cancellone	1	0	SAT
Toscana	7th–6th B.C.	Magliano-Cancellone	1	3	SAT
Toscana	6th B.C.	Magliano Sant' Andrea	0	1	SAT
Toscana	3rd B.C.	Populonia	3	1	SAT
Toscana	6th–5th B.C.	Selvaccia	5	5	SAT
Toscana	6th–2nd B.C.	Vetulonia-Dupiane	2	2	SAT
Toscana	3rd–2nd B.C.	Volterra-Badia	1	0	SAT
Toscana	1st B.C.	Volterra-Osteraccia	1	1	SAT
Toscana	–	Solaia	1	0	MSN
Toscana	6th B.C.	Vulci	0	1	MSN
Toscana	–	Romitorio	0	1	MSN
Toscana		Gonzarelli	0	1	MSN
Toscana		Chianciano	1	1	MSN
Toscana	–	Montebello	1	0	MSN
Toscana		Lago Vasoro	1	0	MSN
		Tot individuals	*220*	*181*	
		Tot sites	*30*	*22*	
Roman period					
Abruzzo	1st B.C.–1st A.D.	Collelongo	4	6	UniPi
Emilia	2nd–3rd A.D.	Bagnocavallo	4	4	UniBo
Emilia	1st–3rd A.D.	Palazzette	4	6	UniBo
Emilia	2nd–4th A.D.	Rimini	9	5	UniBo
Lazio	2nd–3rd A.D.	Castel di Guido	5	5	MPE
Lazio	2nd–3rd A.D.	Via Basiliano	34	26	SAR
Lazio	1st–3rd A.D.	Lucrezia Romana	16	15	SAR
Lazio	1st–3rd A.D.	Lucus Feroniae	27	22	UniRo
Lazio	1st–2nd A.D.	Serenissima (E)	8	6	SAR
Lazio	2nd A.D.	Pagliano	0	1	L
Lazio	2nd–3rd A.D.	Passo Scuro	2	2	MPE
Lazio	4th A.D.	Statua	2	1	L
Marche	3rd–5th A.D.	Suasa	13	19	UniBo
Molise	1st–4th A.D.	Quadrella	22	11	UniBo
Toscana	3rd–4th A.D.	Scoglietto	2	0	MSN
Toscana	3rd–5th A.D.	Settefinestre	1	0	L
Toscana	–	Volterra	0	2	L
		Tot individuals	*153*	*130*	
		Tot sites	*15*	*15*	
Medieval period					
Emilia		Bologna San Lazzaro	6	3	UniBo
Lazio		Baccano	2	2	L
Lazio		Bomarzo	1	0	L
Lazio	6th–7th A.D.	Campidoglio	2	0	L
Lazio	Med.-ostrogoto	Ladispoli	1	2	L
Lazio	7th A.D.	Selvicciola	20	10	UniRo
Lazio	Early Medieval	Testaccio	2	2	L
Molise	7th–8th A.D.	Vicenne CampoChiaro	23	15	UniBo
Toscana	Early Medieval	Badiola	2	0	MSN
Toscana	8th A.D.	Duomo di Chiusi	1	0	L
Toscana	Late Medieval	Impruneta	1	1	L

(continued)

TABLE 1. (Continued)

Region	Date	Archeological site	Males	Females	Location[a]
Toscana	Late Medieval	Pistoia (P. dei vescovi)	2	1	L
Toscana		P.zza Signoria (FI)	13	26	SAT
Toscana	5th A.D.	P.zza Signoria (FI)	2	5	MSN
Toscana		Pieve di Romena	3	2	SAT
Toscana	6th–8th A.D.	Rignano	0	1	MSN
Toscana		Roselle	46	34	SAT
Toscana	XVII century	Sant' Egidio (FI)	4	4	MSN
Toscana	5th A.D.	Santa Reparata (FI)	7	9	L
Toscana		Sestino	38	29	SAT
Toscana		Santa Maria del Fiore (FI)	2	0	MSN
Toscana		Vaiano	8	6	SAT
		Tot individuals	*187*	*150*	
		Tot sites	*21*	*17*	

[a]L = data from the literature, MPE = Museo Preistorico ed Etnografico "L. Pigorini," MSN = Museo di Storia Naturale sez. Antropologia–University of Florence, SAR = Soprintendenza Archeologica di Roma, SAT = Soprintendenza Archeologica della Toscana, UniBo = Museo di Antropologia–University of Bologna, UniFi = Lab. Di Antropologia–University of Florence, UniRo = Museo di Antropologia–University of Rome.

context of the analysis of a Mesolithic sample from Sicily while Borgognini-Tarli and Mazzotta (1986) analyzed changes of body structure in Italian populations from the Bronze Age to the Medieval period. In these two articles, however, long bone lengths were collected from the literature and stature in Borgognini-Tarli and Repetto (1986) was reconstructed using Trotter and Gleser formulae for Afro-Americans (1952, 1977). They followed the conclusion of Formicola (1983), who suggested that the Trotter and Gleser formula for Afro-Americans was the most reliable method to derive stature from long bone lengths on prehistoric Italian samples. However, there is no evidence of the reliability of this regression formula for more recent archeological materials.

The aim of this article is two fold:

1. To analyze the reliability of different regression methods to estimate stature for skeletal remains of populations who lived in Central Italy from Iron Age to Medieval times.
2. To search for trend (or lack of) in stature over the time period considered, using the most reliable regression method.

MATERIALS AND METHODS

The database created for the present article comprised long bone lengths (humerus, radius, femur, tibia) of skeletal remains from archeological sites of Central Italy spanning a time period from the Iron Age to the Medieval period (roughly 9th century B.C. to 15th century A.D.). Long bones measurements were taken on adults with associated remains. The samples measured had no evidence of obvious pathological conditions affecting growth, and were sufficiently well preserved to allow reliable measurements and sex estimation. Sex estimation was based on visual analysis of skeletal features as proposed by Acsadi and Nemeskeri (1970) and Ferembach et al. (1977). We did not consider samples from unclear archeological contexts.

Long bone measurements were taken by only one of us (M.G.) to avoid interobserver errors. In only a few cases, where it was not possible to access skeletal remains, bone lengths were obtained from the literature (Table 1). The following bone lengths, measured as in Martin and Saller (1959), were taken: humerus: length 1 and 2, radius: length 1 and 1b, femur: length 1 and 2, tibia: length 1, 2, and 1b.

The skeletal samples were then attributed to three different chronological and cultural periods. The definition of precise chronological boundaries for a time period covering nearly 2,500 years is difficult for several reasons: the partial overlapping of cultural phases, their different geographical locations over time, and the lack of precise dates for skeletal remains. These difficulties make an exact chronological framing of the materials almost impossible. We thus decided to adopt a simplified chronological scheme as follows: Iron Age (9th B.C.–5th sec. B.C.); Roman period (5th B.C.–5th A.D.); Medieval period (5th A.D.–15th A.D.), as in Borgognini-Tarli and Mazzotta (1986).

Skeletal remains included in the present analysis came from sites in regions in central Italy (Tuscany, Latium, Marche, Abruzzo, Molise) and also nearby regions (Emilia Romagna and Campania) (Fig. 1). The data set includes 1,021 adult individuals, 560 males, and 461 females, from 66 archeological sites for males and 54 sites for females (Table 1).

Choice of regression equation to reconstruct height from long bone length

The first problem addressed was that regression formulae are calibrated on specific modern population samples. Before using these regression formulae to derive stature for archeological skeletal remains, it is necessary to consider how the body proportions of the archeological sample resemble body proportions in these modern samples. As trunk measurements are rarely accessible in skeletal remains of past populations due to the poor conservation of vertebral bodies, in order to control for body proportion similarities it is necessary to rely on an indirect measure of more general body structure similarities as reflected in limb proportions.

The most suitable formula was considered as the regression equation giving the least variability of stature estimates derived from different limb segments in each individual (Gini, 1939; Parenti, 1971; Formicola, 1983, 1989). The parameter Delta of Gini (1939, hereafter DG),

Fig. 1. Italian regions from which the skeletal samples for this study derive. 1 = Emilia Romagna, 2 = Tuscany, 3 = Marche, 4 = Latium, 5 = Abruzzo, 6 = Molise, 7 = Campania.

calculates the average of the difference in stature values obtained from single bones for each individual. Regression formulae with the lowest values of delta are those that were calibrated on human samples with limb proportions most similar with the limb proportions of the sample under study and thus, at least from this point of view, the most reliable.

The analysis of the DG parameter, was carried out on a sample of 179 males and 132 females (Table 2) representing all the individuals with the four bones of the limb segments (humerus, radius, femur, and tibia).

The regression equations tested with DG were those commonly used for stature reconstruction in Italian protohistorical and historical series and also those tested in previous studies for their applicability to Italian prehistoric samples (Formicola, 1983, 1989, 1993; Formicola and Franceschi, 1996; Formicola and Giannecchini, 1999). Seven regression methods were tested: Trotter and Gleser for Whites (TGW) (1952, Table 13), Trotter and Gleser for Afro-Americans (TGN) (1952, Table 13; 1977), Olivier et al. (OLI) (1978), Pearson (PEA) (1899), the two formulae described by Formicola and Franceschi (FLR and FMA) (1996), and the one proposed by Sjøvold (SJO) (1990). Sjøvold' regression equations, although rarely used for Italian series, were also tested because they have the advantage of being independent from sex and ethnic group (Sjøvold, 1990).

For TGW and TGN, stature estimates from the lower limb were obtained using the formulae derived from maximum length of the femur and the maximum length (condylo-malleolar) of the tibia. The use of the TGW and TGN (1952) regression formulae for the tibia requires caution. It has been documented that although Trotter's description of her measurement of the tibia is essentially condylar - malleolar length, the actual measurements most probably did not include the malleolus. This would result in greater stature estimates from the tibia than from other bones (Jantz et al., 1994, 1995). These reservations with the definition of the measurement of the tibia employed by TG 1952, may influence the outcome of the analysis of the DG values when comparing all methods of stature reconstruction using the four long bones at the same time.

To address this problem, we have also calculated statures following TGW and TGN with adjustments to the measurements of the tibia for each individual. This has been done subtracting an average value equivalent to the malleolus (11 mm), as indicated in Jantz et al. (1995). The combined results of the two analyses suggested the most appropriate method for stature reconstructions.

Analysis of stature

Once the most appropriate regression method was identified, it was then used to calculate stature for each individual using all the available long bones. The height value for each individual was therefore given by the average of all estimates calculated from single long bones. Although lower limb bones are more closely related to stature and give more accurate stature values, we decided to use an average of the values obtained from any limb segment for the following reasons:

1. Not all individuals had preserved tibiae and femora and thus using only these bones would have caused a significant reduction of sample size,
2. Using only the femur and tibia when present and the other bones when the former were not present could have caused a nonrandom distribution of the accuracy of estimates.

Using all the available bones allowed us to have a larger sample size, and to enhance comparability of results by reducing effects of nonrandom distribution of less accurate estimates. Given that one of the aims of this study was the analysis of diachronic changes in stature, the comparability of results, prior to the accuracy of estimates, was our main interest. Calculating the stature of an individual as the average of different stature estimates from different limb segments was then the most appropriate choice.

We also verified whether changes of stature over time were associated with changes in sexual dimorphism and changes in intralimb proportions. Sexual dimorphism was calculated as the percentage ratio of female and male stature values. Intralimb indices were calculated following Martin and Saller (1959). Statistical analysis was carried out to investigate potential significant differences over time by using the analysis of variance (ANOVA for height values and long bone lengths, and Kruskall-Wallis test for intralimb proportions) and multiple comparison tests between average values (Siegel and Castellan, 1988). Because of sample size we decided not to perform an analysis of stature changes over time on a regional level. However, we compared archeological sites with larger sample sizes within each time period, with the aim of presenting a framework for those archeological skeletal series not included in the present work or yet to be studied.

TABLE 2. Mean delta values (cm) for each of the regression methods tested

	Males								Females							
	Delta Tot		Iron		Roman		Medieval		Delta Tot		Iron		Roman		Medieval	
	A	Un	A	Un	A	Un	A	Un	A	Un	A	Un	A	Un	A	Un
TGW	2.8	2.7	3.1	2.9	3.0	2.7	2.5	2.6	3.0	3.2	3.0	3.3	3.2	3.3	2.9	2.9
TGN	2.6	2.4	2.6	2.2	3.0	2.6	2.5	2.4	2.8	2.8	2.6	2.7	3.2	3.1	2.8	2.7
FLR	2.7		2.4		3.0		2.7		2.5		2.4		2.8		2.5	
FMA	3.2		2.9		3.5		3.2		2.8		2.7		2.9		2.8	
PEA	2.5		2.5		2.3		2.5		2.3		2.3		2.4		2.1	
OLI	2.8		3.0		2.9		2.5		3.9		4.2		3.8		3.7	
SJO	3.1		3.1		3.1		3.3		3.4		3.5		3.6		3.2	
n	179		59		50		70		132		46		39		47	

A = Adjusted; Un = Unadjusted; TGW = Trotter and Gleser for Whites (1952); TGN = Trotter and Gleser for Afro-Americans (1952, 1977); OLI = Olivier et al. (1978); PEA = Pearson (1899); FLR, FMA = Formicola and Franceschi (1996); SJO = Sjøvold T. (1990).

RESULTS AND DISCUSSION

Choice of regression equation to reconstruct height from long bone length

The results of the analysis of DG parameter are presented in Table 2, divided by sex and time period.

For females, the combined results of the two analyses (with unadjusted and adjusted TG formulae for the tibia) were very consistent, both within each time period and in the whole sample (Delta tot). The equations with the lowest values of delta were PEA and FLR. Adjustments to the measurements of the tibia had little effect on the DG values for the TGW and the TGN equations.

The pattern of DG values for the male sample showed a different picture. In the whole sample (Delta tot), for males the equations with the lowest values of delta were TGN and PEA. When the adjusted TGW and TGN formulae were applied PEA showed the lowest values of DG. Highest variability of stature values from the four long bones for each individual (higher values of delta) occurred with OLI, SJO, and FMA.

For males the DG values by period presented a different pattern that changed when considering unadjusted or adjusted formulae. Looking at the unadjusted values first, TGN resulted to be the most suitable formula for the Iron Age and Medieval period. In the Iron Age the second lowest value of DG was given by FLR and in the Medieval period by PEA. In the Roman period PEA was the most suitable formula and TGN the second. Thus, using unadjusted TG formulae, TGN resulted to be the equation giving the lowest or the second lowest DG values in four of the four cases (the whole sample and the three time periods), whereas PEA in three of the four cases.

On the other side, with the adjusted TG formulae PEA was the most suitable formula for the Roman and Medieval period and the second for the Iron Age (with FRL as the first). TGN appeared to be the most suitable equation in the Medieval period only, and together with PEA, TGW, and OLI. Using the adjusted TG formulae PEA had the lowest or second lowest DG values in four of the four cases, and TGN in two of the four.

In the light of these results, and taking into account the problems with the measurements of the tibia we decided to use the PEA regression method. A remark on using PEA relates to the result that stature estimates from the humerus were always underestimated when compared to those calculated by other long bones. This shortcoming, already noted by Formicola (1983) in prehistorical material, should not discourage the use of these formulae, with the exception of those skeletal samples where the most common long bone available to calculate stature is the humerus.

Analysis of long bone length and intralimb proportion

The results from the analysis of long bone lengths and intralimb proportions are shown in Tables 3 and 4. Although the different limb segments did not have the same sample size, the data provide a first indication of the existence and magnitude of diachronic changes in stature. A statistically significant decrease in the average length for each of the limb bones was evident in males when comparing the Iron Age to the Roman period. The extent of this decrease, expressed as the difference in the mean (both the absolute and the percentage value), was more marked for the radius and tibia, than the humerus and femur (Table 4). A similar trend, with a significant reduction in length for each limb segment, was evident in the female sample (Table 4).

The comparison between the Roman and Medieval period samples showed a trend opposite to that of the Iron Age-Roman period transition, with a statistically significant increase in the average bone length of all limb segments, both in males and females. The differences relative to the lower limb bones in both sexes were particularly marked (Table 4).

Long bone length of Iron Age and Medieval period individuals differed only slightly in both sexes and comparisons for each limb bone were not statistically significant. These variations of length of the four long bones in the three study periods explained the observed changes of intralimb proportions calculated on single individuals (Table 5).

Stature changes over time

Stature estimates derived using PEA are presented in Table 6, divided by periods and sexes. These show a clear and homogeneous time trend similar for both sexes with a decrease of average values of stature in the transition from the Iron Age to the Roman period and an increase from the Roman to Medieval period. In males average stature decreased 2.2 cm in the Roman period, and in females 1.2 cm. In the Medieval period, compared to the Roman period, average stature estimates increased by 2.5 cm in males and 2.4 cm in females. These

TABLE 3. Mean length (mm), standard deviation (SD) and coefficient of variation (CV) of limb bones in the three time periods

	Iron age				Roman period				Medieval period				
	N	Mean	SD	CV	*N*	Mean	SD	CV	*N*	Mean	SD	CV	*P*
Males[a]													
H1	111	325.2	15.9	4.9	99	320.5	14.9	4.6	124	324	25.7	7.9	ns
R1	106	248.5	12.6	5.1	80	237.7	12.2	5.2	120	247.1	12.3	5	$P < 0.001$
F1	187	454.2	20.2	4.4	122	445.5	19.8	4.5	145	456.3	37.5	8.2	$P < 0.001$
T1	119	370.2	20	5.4	107	358.2	19.4	5.1	127	374.1	20.2	5.4	$P < 0.001$
Females													
H1	94	295.3	14.2	4.8	80	292.3	13.3	4.6	97	297.8	12.1	4.1	$P < 0.05$
R1	74	220.6	10.4	4.7	62	215.1	18	8.3	86	221.1	11	5	$P = 0.05$
F1	153	419.8	18.1	4.3	107	406.9	18.1	4.4	111	419.7	19.1	4.6	$P < 0.001$
T1	85	341	15.2	4.5	82	328.9	17.5	5.3	101	340.6	15.4	4.5	$P < 0.001$

P values from ANOVA.
[a] H1 = maximum length of humerus, R1 = maximum length of radius, F1 = maximum length of femur, T1 = maximum (condylo-malleolar) length of tibia.

TABLE 4. Changes in long bone length (in mm and in percentage) by period and sex

	Males[a]									Females								
	Iron-Rom			Rom-Med			Iron-Med			Iron-Rom			Rom-Med			Iron-Med		
	mm	%	*P*	mm	%	*P*	mm	%	*P*	mm	%	*P*	mm	%	*P*	mm	%	*P*
H1	−4.7	−1.4	ns	+3.5	+1.1	ns	−1.2	−0.4	ns	−3.0	−1.0	ns	+5.5	+1.9	*	+2.5	+0.8	ns
R1	−10.8	−4.3	**	+9.4	+4.0	**	−1.4	−0.6	ns	−5.5	−2.5	ns	+6	+2.8	0.06	+0.5	+0.2	ns
F1	−8.7	−1.9	*	+10.8	+2.4	**	+2.1	+0.5	ns	−12.9	−3.1	**	+12.8	+3.1	**	−0.1	−0.0	ns
T1	−12	−3.2	**	+15.9	+4.4	**	+3.9	+1.1	ns	−12.1	−3.5	**	+11.7	+3.6	**	−0.4	−0.1	ns

P values from multiple comparison analysis on bone lengths.
[a] H1 = maximum length of humerus, R1 = maximum length of radius, F1 = maximum length of femur, T1 = maximum (condylo-malleolar) length of tibia.
$^*P = < 0.05$, $^{**}P = < 0.001$.

changes, for each comparison (Iron Age-Roman period, and Roman period-Medieval period), were statistically significant for both sexes. No significant differences could be found when comparing average stature in the Iron Age to the Medieval period for either sex. The variability of stature, as expressed by the coefficients of variation showed small differences over time in both sexes. The average values of sexual dimorphism remained more or less constant in the three time periods (92.7 in the Iron Age, 92.9 in the Roman period, and 92.7 in the Medieval period); the differences were not statistically significant.

The archeological material examined, although numerically appropriate for temporal comparison, did not allow an analysis of stature changes at the regional level within and between periods. In an attempt to present stature variations over time in a more focused way and with the aim of providing a framework for the comparison of other skeletal series, we compared stature values of the numerically more important skeletal samples divided per periods and sexes (Fig. 2). Within each period there was a high variability among stature values for different skeletal series. However, it is worth noting that, for both sexes, the stature values for the Roman period skeletal series never exceeded the values of skeletal samples of the Iron and Medieval Ages, a result that confirms the decreasing trend observed in the skeletal series for the Roman period.

This picture of changes in body structure over time, which seems to emerge from our analysis, must be interpreted with extreme caution by taking into account some general considerations. The period under study spans nearly 2,500 years and it was characterized in Italy by important and numerous social, economic, and population changes. Any attempt to propose a microevolutionary model with general validity is particularly difficult because of the large cultural and socioeconomic differentiation within and among periods and the significant migratory fluxes, particularly during the Roman and Medieval periods. Additionally, the geographical area examined—although relatively limited—cannot be considered as homogeneous, in that the Apennine mountain range divides it into two distinct subregions along the north-south axis, with different populations living on the two sides of it. As an example, in the Iron Age the northern portion of the area considered on the west side was largely inhabited by Etruscan populations, whereas Italic populations (e.g. Picenians, Samnites, etc.) occupied the east side (see Macchiarelli et al., 1995; Coppa et al., 1998).

A detailed analysis of the causes and consequences for changes in body structure over time is beyond the scope of this article. This kind of analysis is even more difficult because relatively few systematic and methodologically homogeneous studies have been carried out on life and health of populations of these time periods.

A number of the skeletal remains in our sample were analyzed many years ago, when only basic anthropometrical and typological information was given. In this respect it is interesting to report what Borgognini Tarli and Mazzotta (1986) wrote in their review (p. 154): "A general conclusion is that we have to face a rather unsatisfactory situation from the anthropological point of view. [...] One gains the impression that many articles, also among the recent ones, were not conceived in view of a future elaboration." More than twenty years later, the situation is only slightly improved, with relatively few, carefully designed studies published on the lifestyle and health conditions of specific populations (e.g.

TABLE 5. *Mean, standard deviation (SD) and coefficient of variation (CV) of tibia-femur (T1/F2) and radius-humerus (R1/H1) indices in the three time periods for both sexes*

	Iron age				Roman period				Medieval period			
	N	Mean	SD	CV	*N*	Mean	SD	CV	*N*	Mean	SD	CV
Males												
T1/F2[a]	103	82.0	2.5	3.0	87	81.1	2.5	3.1	109	82.2	2.5	3.0
R1/H1[b]	80	76.7	2.3	3.0	67	74.8	3.0	4.0	98	75.9	2.0	2.6
Females												
T1/F2[a]	75	82.4	2.4	2.9	69	81.9	2.6	3.2	81	82.1	2.1	2.6
R1/H1[b]	62	75.0	2.5	3.4	52	74.1	2.6	3.5	72	74.4	2.5	3.3

[a] T1 = maximum (condylo-malleolar) length of tibia, F2 = bicondylar length of femur.
[b] R1 = maximum length of radius, H1 = maximum length of humerus.

TABLE 6. *Mean values of stature estimates (cm) derived using Pearson (1899), standard deviation (SD), and coefficient of variation (CV) in the three time periods*

	Iron age				Roman period				Medieval period				Differences		
	N	Mean	SD	CV	*N*	Mean	SD	CV	*N*	Mean	SD	CV	Iron-Rom	Med-Rom	Iron-Med
Males	220	166.6	4.0	2.4	153	164.4	3.9	2.4	187	166.9	4.3	2.6	2.2*	2.5*	−0.3
Females	181	154.3	3.7	2.4	130	152.1	3.4	2.2	150	154.5	3.4	2.2	2.2*	2.4*	−0.1

**P* values < 0.001.

Macchiarelli et al., 1988; Macchiarelli and Salvadei, 1989; Manzi et al., 1999; Belcastro et al., 2007).

These studies, at the same time, are indicative of marked regional differences. For example, Manzi et al. (1999) and Belcastro et al. (2007) both analyzed populations from central Italy who lived at the end of the Roman Imperial period and in the early Middle Age—a period of marked political, social, and economic transitions. The former studied three skeletal samples from the north-central part of Latium, whereas the latter examined two skeletal series from Molise, on the east side of the Apennines. The results show that in the Latium area a clear discontinuity is evident in the lifestyle and health conditions of these populations at the transition from the Roman to the Medieval period, whereas this is not apparent in the Molise region. This seems to suggest that "... the transition occurred at different times and in different ways in Italy" (Belcastro et al., 2007) making it difficult to draw general inferences for the populations from central Italy.

Only with detailed information such as this for each series can one begin to investigate changes in the physical structure of populations in terms of genetic and environmental factors influencing health. The observed diachronic changes, although suggestive, must be interpreted with caution. We would only like to point out that the statistical analysis of the results seems to exclude that the observed temporal trend is merely artifactual.

The results of stature reconstruction and the analysis of body proportions classify the populations living during the time periods considered as "medium-short," particularly those of the Roman period. They confirm but add more details to previous observations by Borgognini Tarli and Mazzotta (1986) and Borgognini Tarli and Repetto (1986). These authors, working on long bones length data collected from the published literature, reported what they described as an overall homogeneity of the Italian population from the Bronze age to Medieval period—although inspection of their tables clearly shows a trend not dissimilar to what we have presented above.

Further, it can be noted that changes of limb length over time are more pronounced in the distal rather than the proximal elements in both limbs (a feature also evident in the data presented by Borgognini Tarli and Mazzotta, 1986). These data support studies on modern populations showing the distal elements to be more sensitive to changes in living conditions than the proximal elements (Jantz and Jantz, 1999; Holliday and Ruff, 2001; Bogin et al., 2002). The relative reduction of the lower segment and the observed reduction of stature during the Roman period may suggest that the populations in our samples in this time period were experiencing living conditions less favorable as compared to those of the Iron Age and Medieval period.

CONCLUSIONS

The aim of the research carried out here on skeletal series from archeological sites of central Italy was twofold: 1) to provide general, practical indications for the criteria to use to select of the regression equations to determine stature from skeletal materials, 2) to verify the existence of diachronic changes in body structure of the populations examined. Differences may exist among skeletal samples of different time periods regarding which is the most appropriate regression method to use when reconstructing stature from long bones. The Delta of Gini parameter, comparing differences in estimates derived from different bones, was found to be an efficient method. It allowed us to determine for a particular skeletal sample the most appropriate regression equation to use. In our work Pearson (1899) and Trotter and Gleser formulae for Afro-Americans (1952, 1977) provided the most consistent stature estimates. In future we need to verify if this is valid for other skeletal series. On the other hand, Trotter and Gleser for Whites (1952) and Olivier et al. (1978) did not produce reliable estimates, at least for stature reconstruction in the archeological samples we examined.

In using the TGN and TGW equations one must also be aware of the problems related with the definition of the measurement of the tibia. It might be interesting, in this regard, to measure the tibia, if possible, with and

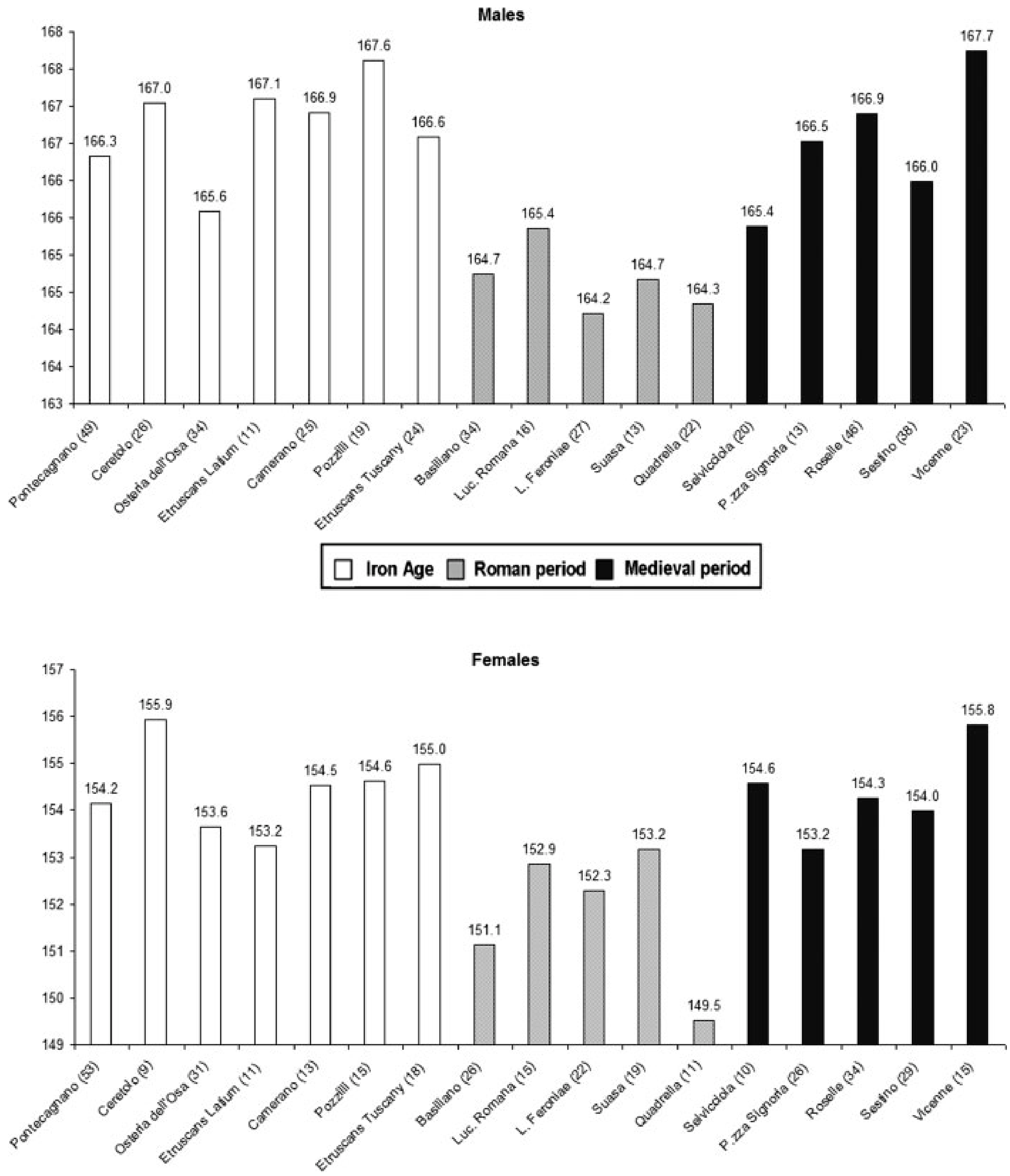

Fig. 2. Mean values of stature for selected archeological series.

without the malleolus to see if and how this affects the results. More in general this underscores the importance of using bone measurements that agree with those used in the calibration samples.

Factors to be considered when choosing a particular regression formula relate to the available skeletal materials for study and the goal of the research. Comparability of results is important in an analysis on large skeletal series covering a long time period. In our sample body proportions did not vary significantly over time. In this case, it is advisable to choose a regression formula that best fits the sample on the whole to enhance comparability of results, although there might be differences in time or space in the estimate accuracy of the method chosen. As a general comment we recommend checking body proportion variations over time and to look for body structure similarities between the reference groups of regression formulae and the target skeletal samples.

The situation is different when there is no need for comparison over time and space and the aim is to provide the most accurate stature estimate for the individual description of the osteological material. In this case it might be important to choose the most appropriate equation, providing the lowest values of delta for the specific time period. In addition to these general indications, we must add that the application of the same formula for males and females may reduce possible differences linked to sexual dimorphism in the skeletal samples under study.

Our analysis of stature and limb proportions in human populations living in central Italy from the Iron Age to the Medieval period provides an interesting picture. The observed temporal trends mainly consist in a reduction of stature and of the distal segments of upper and lower limbs in the Roman period samples. There are several possible factors relating to socioeconomic context and health that might be responsible for this trend.

The results point to the need for a systematic analysis of changes in living conditions and health over time. Only data collected using a consistent method can be of use in studying the causes of changes in body structure over time. At the moment, the results of the present article provide a framework within which data gathered from other studies of archeological relevance can be compared.

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