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Title

A bioarchaeological approach to the reconstruction of changes in military organization among Iron Age Samnites (Vestini) from Abruzzo, central Italy.

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ABSTRACT

The Samnites were an Iron Age population that shifted from warlike mountain dwellers to the largest sociopolitical unit of central Italy, able to dispute with Rome the domination over the peninsula. Archaeological and historical evidence suggests that this major shift in the scale of conflict may have involved a reorganization of the military system, which changed from an elite militia to a conscript or standing army from the Orientalizing-Archaic (800-500 BC) to Hellenistic times (400-27 BC). We propose a bioarchaeological framework jointly analyzing skeletal properties and funerary treatment in male Samnites to investigate on this shift in military organization. We anticipated that, when Samnites had an elite militia, the warring force was constituted by the wealthier segments of the society. Conversely, we expected the warring force of the standing/conscript army to be mainly drawn from the lower social strata. We considered high asymmetry in J, a measure of humeral torsional rigidity (calculated via cross-sectional geometry, CSG) as a proxy for pre- and peri-adolescent-onset weapon training. The social standing of the individual was approximated via funerary treatment analysis (Status Index). Results show that in the Orientalizing –Archaic period, humeral asymmetry and Status Index are positively correlated, and the high-status subsample shows significantly higher asymmetry than the low-status subsample. Among Hellenistic Samnites, no correlation between Status Index and humeral asymmetry is present, and the low-status subsample is the most lateralized.

Results support the use of CSG in a strong theoretical framework to investigate past changes in military organization and their correlates in terms of sociopolitical development, alterations of power relationships, and warfare.

Warfare in prehistory and the relationship between war and social complexity is an issue that has long intrigued scholars in human disciplines (Keegan, 1993; Keeley, 1996; Kelly, 2000; Otterbein, 2004; Guilaine and Zammit, 2005; Martin et al., 2012). Stein (2001) noticed that investigations of past social change have been rare because it is difficult to identify power relationships in the archaeological record. He proposes to do so by integrating textual and iconographic sources with material evidence. Bioarchaeology, through the joint analysis of skeletal data and archaeological information (and historical sources, when available), provides a powerful tool to test hypotheses on environmental and social changes that are expected to have had biological consequences. The main source of raw data used to create an empirical link between warfare and skeletal properties has been the study of past trauma and paleopathology (Walker, 2001). Recently, this kind of data has been studied in strong theoretical frameworks that allowed for the investigation of complex sociopolitical processes (Glencross, 2011; Martin et al., 2012; Pérez, 2012; Robbins Schug et al., 2012; Tiesler and Cucina, 2012; Knüsel and Smith, 2014a,b). Skeletal injuries can provide evidence of the occurrence of armed violence, and the archaeological context can allow for a distinction between individuals that were victims or perpetrators of violence. However, preserved injuries are inherently rare in the skeletal record, and the identification of warriors is often not straightforward. Perez (2012) introduced the concept of 'politicization of the dead' and suggests that the manipulation of the corpse may provide information on the communities at both ends of violence. There are various ways in which the body is 'culturally shaped' by the practices and behavior of the group in life as well as in death. One of those ways may be the early onset and frequent practice of unimanual weapon training, which results in high levels of asymmetry in humeral torsional rigidity (J, calculated via cross-sectional geometry, CSG; Churchill and Rhodes, 2009; Sparacello et al., 2011). Bioarchaeological and experimental evidence demonstrates that high humeral lateralization in J is common in past and modern groups whose shared behavioral repertoire included frequent and stressful unimanual tasks like asymmetric sports and throwing activities (Trinkaus et al., 1994; Churchill et al., 1996, 2000; Shaw and Stock, 2009). Bone epigenetic functional adaptations have the advantage of not being episodic, but expected in a non-pathological setting when stressful, highly characterizing activities are practiced since pre-adolescence (Pearson and Lieberman, 2004; Ruff et al., 2006). We analyze asymmetry in humeral torsional rigidity in the context of a shift in sociopolitical organization of an Iron Age population, which is likely to have involved a change in military organization from a small aristocratic militia to a large army. We test the hypothesis that this shift in military organization caused the widespread use of weapons to shift through time from the elite segment of the society to the lower social strata.

Archeological and historical background

The European Iron Age (from about 1000 BC to Roman Conquest, depending on the population under exam) was a time of demographic growth, intensification of agriculture, and increasing sociopolitical complexity (Peroni, 1989, 1992; Cunliffe, 1994, 2008; Guidi, 2000; Boatwright et al., 2004). In the Mediterranean, early states based on elected representatives were developing from simpler forms of stratified social organization based on kinship ties, which can be generally referred to as chiefdoms (Earle, 1997; Barker et al., 1996; Kristiansen, 1998, 1999; however we are not operating in a strict social evolutionary model here, see Pauketat, 2007). One of those shifts in power relationships is believed to have happened among the Samnite people of central Italy with the passage from the Orientalizing-Archaic period (c. 800-500 BC) to the Hellenistic period (c. 400-27 BC). The term ‘Samnites’ was used by ancient Roman and Greek historians to identify numerous Oscan-speaking groups which called themselves ‘Safineis’ (in addition to other names specific to their sociopolitical unit, e.g. Pentri, Irpini, Vestini, and several others), and who migrated into central Italy probably during the Bronze Age (La Regina, 1989).

A few historical accounts describe Oscan people of the Orientalizing-Archaic period as ‘isolated mountain dwellers’ known for their proclivity to raid neighbors (Salmon, 1967; Tagliamonte, 1994, 1997, 1999, 2009). By the Hellenistic period (400-27 BC), Samnites become one of the largest political and military powers of the Italian peninsula, and were able to dispute with the Roman Republic the hegemony over central Italy (La Regina, 1968; Tagliamonte, 1997). In addition to this change in the scale and scope of conflict, archaeological and historical evidence strongly suggests that Samnites experienced profound changes in sociopolitical organization.

In the Orientalizing-Archaic period, burials presumably belonging to the social elites were characterized by the presence of warrior paraphernalia (swords, javelins, and protective gears) and banqueting sets (pitchers, serving platters, skewers, and andirons; Tagliamonte, 1997, 1999). The association between social standing and warlike prowess is also suggested by iconographic evidence, such as the statue of the Warrior of Capestrano (c. 6th century BC), a warrior-leader or king, which is depicted with a sword, a couple of spears, and an axe, as well as wearing defensive gears (d’Ercole, 1990; Calderini et al., 2007; d’Ercole and Cella, 2007a,b). Also burial spatial patterns suggest the rise of permanent elites based on kinship (Barker et al., 1996; Tagliamonte, 1997; Bietti-Sestieri et al., 2000). The joint analysis of skeletal remains and funerary treatment evidences an unequal distribution of wealth among several grave circles, which represented different patrilinear lineages (Bondioli et al., 1986; Rubini, 1996). This suggests the development of stable hierarchies in which the power was held by an aristocracy that was legitimized by extended kin coalitions (d’Ercole, 1990; d’Ercole et al., 2003). Small-scale conflict between neighboring communities within the Samnite stock was common, as suggested by ancient historical accounts and by the high incidence of sword injuries and cranial trauma in many Orientalizing-Archaic necropoli, especially in males (Macchiarelli et al., 1981; Robb, 1997; Paine et al., 2007).

In the Hellenistic period, weapons disappear from grave assemblages. In chamber tombs, presumably pertaining to the social elites, banqueting sets are now accompanied by items related to gymnastic activity (metal tools to scrape the body from sweat and sand, and ointment containers), culture (inkpots and pen-nibs), and leisure (dices, gaming pawns; Copersino and d'Ercole, 2003). Historical accounts report that Samnites by this time functioned as a highly decentralized, democratic state, composed of hierarchically-organized and elected administrative units (Salmon, 1967; La Regina, 1989; d'Ercole, 1990; Tagliamonte, 1997). During times of war – which were very frequent and included three major wars with Rome (the Samnite Wars, 343-290 BC) – leadership was unified and power exerted by the Samnite League, a central political and military entity that confederated the Oscan-speaking tribes (Lepore, 1989, 1992; Tagliamonte, 1994). After the Samnite Wars, the Roman Republic imposed a truce of subordination but substantial independence (*civitas sine suffragio* status). However, Samnites were still able to mobilize armies that sided against the Roman Republic during the Phyrric War (280-275 BC), the Second Punic War (218-201), the Social War (91-89 BC), the Silla-Marius Civil War (82 BC), the Rebellion of Spartacus (73-71), and even the Catiline Conspiracy (62 BC). Samnites were finally assimilated into the newly-formed Roman Empire in 27 BC (La Regina, 1968; Tagliamonte, 1997).

The major change in the scale, frequency, and degree of organization of warfare that accompanied the shift in sociopolitical organization is believed to have had a major impact on military organization. The wars of the Hellenistic period were fought by large-scale armies fighting pitched battles for the purpose of territorial conquest (Bradley, 2000; Boatwright et al., 2004). Before this date, scholars suggest that simpler and less structured forms of warfare prevailed, consisting of raiding and looting nearby communities for revenge, booty, or social and political prestige (Salmon, 1967; Boatwright et al., 2004; Claessen, 2006). In the Orientalizing-Archaic, it is believed that access to the army was limited to the social elites, because only wealthy individuals could afford to maintain the expensive gear for waging war (Hammond, 1959; Hanson, 1989; Otterbein, 2004). During this time, warriors served as followers of an aristocratic leader who had organized the enterprise (Boatwright et al., 2004). Conversely, the large standing or conscript armies that were necessary for greater-scale expansionistic warfare drew the bulk of the warring force from the lower social strata (Otterbein, 1970; Claessen and Skalnik, 1978). Such transition has been best historically documented for Rome: in the fifth century BC, social organization changed from a monarchy to a republic, and by the fourth century legionaries started to receive a daily stipend (Bradley, 2000; Boatwright et al., 2004).

Purpose of the research

It appears that there was a difference in which social strata waged war between the small aristocratic militia and in large standing armies typical of states. Based on archaeological and historical evidence and analogies with the Greek and Roman societies, we presume that in the Orientalizing-Archaic period Samnites had a small aristocratic militia, and developed a conscript or standing army in the Hellenistic period. When diachronically analyzing the skeletal properties of Samnites across social strata, we expect to be able to detect this shift in military organization. We propose a bioarchaeological research framework where high humeral asymmetry in torsional rigidity is used as a proxy for the pre- and peri-adolescent onset of weapon training (at the time, swords were single-handed, and the javelin was the most important weapon), and a numerical index calculated from grave good richness (the Status Index, see below) is a rough proxy for social standing. We therefore expect: 1) a significant positive correlation between humeral bilateral asymmetry and Status Index in the Orientalizing-Archaic. When dividing the Status Index in categories, the subsample of individuals with higher status should show a significantly higher average humeral asymmetry when compared to the subsample of individuals with lower status; 2) the correlation should disappear, or change sign, when analyzing Hellenistic skeletal series.

MATERIALS AND METHODS

The 361 male individuals included in this study belong to 11 Orientalizing-Archaic and Hellenistic necropoli (Table 1) falling within the territory of Abruzzo (central Italy, Figure 1). Ten necropoli are located in close proximity to each other in the Aterno River Valley; one, Alfedena, is c. 50 Km south (Figure 1). The Aterno River Valley necropoli belong to the Vestini people, while Alfedena was settled by the Pentri people. Both people belonged to the Oscan ethno-linguistic group, and were part of the later Samnite League.

[Insert Figure 1 and Table 1 about here]

The Aterno River Valley skeletal series are preserved in the museum ‘Musé’ at Paludi di Celano (Avezzano), Abruzzo Region. The Alfedena skeletal series is preserved in part in the museum ‘Museo di Antropologia Giuseppe Sergi - Polo Museale Sapienza’ (Rome), Lazio Region, and in part at the Università de L’Aquila (L’Aquila), Abruzzo Region. Most of the necropoli have been excavated in the last decades, and anthropological data have been the focus of several Master’s and Doctoral Theses (Piccirilli, 1999; Bestetti, 2002; Ridolfi, 2002; Melandri, 2005; Napolitano, 2012; Sparacello, 2013), but are largely unpublished except for Fossa (Cosentino et al., 2001; Copersino and d’Ercole, 2003; d’Ercole and Benelli, 2004) and Alfedena (Coppa et al., 1981; Paine et al., 2007; Sparacello et al., 2011). The individuals included constitute the totality of the specimens preserving at least a fragment of both humeri which was appropriate for the CSG analysis.

Cross-Sectional Geometry

We employed the Cross-Sectional Geometry (CSG) method to reconstruct activity-influenced functional adaptations of Samnite’s upper limb. The method is based on the theory that bone tissue responds dynamically to bending stresses and strains to optimize itself to its mechanical environment (Lovejoy et al., 1976; Lazenby, 1990; Pearson and Lieberman, 2004; Ruff et al., 2006; Ruff, 2008). The size and shape of the cross-sections of long bones can be therefore analyzed through the same principles used by engineers in designing structures, in this case hollow beams. It has been shown that cross-sectional properties inform on the prevalent mechanical environment of an individual (Ruff et al., 2006), and are particularly sensitive to activities performed at pre- and peri-pubescent ages (Pearson and Liebermann, 2004). The integration of quantitative data derived from CSG with archaeological information has been used to make inferences about the subsistence strategies, and mobility levels of past populations (e.g. Larsen, 1995, 1997; Holt, 2003; Stock, 2006; Marchi et al., 2006, 2011). However, we agree that a cautious approach to CSG data interpretation is advisable, and that important caveats – mainly related to sample size and to the ontogenetic phase on which bones are most responsive to activity – need to be addressed before making inferences about 'habitual' activities of past populations (Meyer et al., 2011; Jurmain et al., 2012).

Cross sections were reconstructed in a non-invasive manner using the SolidCSG method (Sparacello and Pearson, 2010), a modified version of the Latex Cast Method (O'Neil and Ruff, 2004), based on periosteal molds and regression equations (Stock and Shaw, 2007; Sparacello and Pearson, 2010; Macintosh et al., 2013). The CSG variable analyzed here is the polar second moment of area J, which corresponds to the torsional and (twice) average bending rigidity of the shaft. Polysiloxane molds of the periosteal contour were taken at mid-distal humerus (35% bone length from the distal end), using bone lengths defined by Ruff (2002).When possible, prior to taking periosteal molds, bones were positioned according to the appropriate reference axes (Ruff, 2002). When length could not be estimated but the distal portion of the humerus was available, the level corresponding to 35% of bone length was approximated as the midpoint between the most proximal extension of the medial and lateral epicondyles, and the most distal extension of the deltoid tuberosity.

The effect of inaccurate location of the section on the error ranges of femoral and tibial cross-sectional parameters has been explored in previous research (Sládek et al., 2010). The authors found a greater influence of inaccurate positioning on tibial J than on femoral J. In order to be reasonably accurate, the estimated location of the midshaft tibial section should be determined within a maximum range of 1.4 cm from the actual section. However, this is mainly due to the rapid longitudinal changes in size and shape along the tibia, because for the more regular femur the range increases to 7.4 cm. A similar study has not been yet performed on the humerus. However, the portion of the humeral diaphysis where we estimated the location of the section is not subject to significant changes in area or shape, because it is not influenced by the epicondyles or by the deltoid tuberosity. We evaluated the amount of change in J across the humeral shaft from the section placed at 30% of the humeral length to the section placed at 40% of humeral length in 20 modern humeri (data from pQCT scans provided by Colin Shaw). The mean change in J between the 30% and 40% sections is 7.11%. This value is an estimate of the maximum error possible in the determination of J. We expect the error in humeral bilateral asymmetry to be lower for two reasons. First, the 30% and 40% sections are often influenced by the epicondyles and by the deltoid insertion, respectively. The 35% section falls in a portion of the diaphysis where there is no direct muscle activity, and it is typically the location where the bone is most constricted in circumference and experience minimal longitudinal variations in shape and area. Second, the difference in the estimated position of the section between the right and left humeri has been minimized by placing side by side the two fragments of humeral diaphyses during data collection. We believe that estimating the level of the section in this setting is a reasonable approximation in order to maximize sample size. Results obtained by excluding the individuals for which the position of the cross section was estimated will be provided.

Individuals under exam were characterized based on their degree of humeral bilateral asymmetry in J. Humeral bilateral asymmetry was calculated using the formula $[(J_{max} - J_{min})/J_{min}] \times 100$ following previous studies (Rhodes and Knüsel 2005; Sparacello and Marchi 2008; Sparacello et al. 2011).

Status analysis.

Burials are widely used in archaeology to make inferences about wealth, status, and role of the deceased individual, as well as to make interpretations of the political structure of past societies (Saxe, 1970; Binford, 1971; Peebles, 1971). However, it is problematic to make a direct inference on the world of the living by looking at the way they treated their dead. Various studies have explored how funerary symbolism may be misleading due to the complex factors that mediate between status in life and treatment in death (Ucko, 1969; Hodder, 1980, 1982; Parker-Pearson, 1982; Shanks and Tilley, 1982; Samson, 1987; Morris, 1992; Brown, 1995). Moreover, not all the aspects of social organization are equally likely to be reflected in the archaeological record of burials (O'Shea 1981, 1984). In addition to theoretical problems, the nature of burial data is fragmentary (not all the grave goods preserve) and selective (not all the individuals are buried) (Härke, 1997). The inference on the social status of an individual based on grave goods may be therefore biased by assumptions that are not entirely testable, and only general inferences can be made.

With all the above caveats in mind, in this study we employed a simple way to obtain what we posit is a correlate of the social status of the individuals: the Status Index (SI), calculated from the list of grave goods associated with the burial (Bernabei et al., 1995; Cuozzo, 2003; D'Andrea, 2006; Melandri, 2010). Given the differences in grave goods composition, the SI was calculated separately for the Orientalizing-Archaic and the Hellenistic period (Sparacello, 2013). Grave goods were divided in simple functional categories (k) (e.g. weapons, grilling equipment, banqueting equipment, food containers, pins and brooches); for each burial (h), the SI is calculated by multiplying the number of items (N) in each category for its Coefficient of Status (Cs), and then by making the sum of the value obtained for all categories that are present in the grave (Sum Type method):

$SI(h)= \Sigma(k)\ [Nk\times Cs(k)]$.

The Coefficient of Status takes into account how rare a category is, and how many other items are present is the grave where the category was found. As a result, it weights the importance of a category in determining how 'elite' a burial was. A coefficient is calculated first for each category in each burial. If N(k) is the number of burials that contain the k category, and N(hk) is the number of items present in a burial that contains that category, the Coefficient of Status of k in each burial h is calculated as:

$Cs(hk)=[N(hk)/N(k)]$.

The Coefficient of Status of a category k for the whole sample is calculated by summing the coefficients calculated for each burial:

$Cs(k)= \Sigma(h)[N(hk)/N(k)]$.

The raw data on the frequencies of each category in each burial, as well as the matrices with the calculation of the Status Index are available in Sparacello (2013). We used the Sum Type method to calculate the Status Index (rather than the Richest Type method) due to the simple categories we used, which did not take into account whether a particular item was a 'prestige item', i.e. finely crafted or imported. This lack of precise determination of the qualitative nature of grave goods means that a significant portion of possible information on 'richness' may have been overlooked. A typological analysis of each grave good would likely give a more accurate depiction of the level of prestige associated with a burial. Moreover, a comprehensive analysis of the context of the funeral rite might give information on the relative importance of certain categories, allowing for the calculation of a weighted Coefficient of Status (Cuozzo, 2003). However, these studies have not been performed yet for most of the necropoli included in this research. Future analyses and interpretations could certainly benefit from a more detailed assessment of the quality of the items used to estimate status. However, on his monograph about the archaeology and history of Samnites, Tagliamonte (1997) notes that rich burials are most often quantitatively rather than qualitatively rich, because the item categories he considered were largely similar to poorer burials.

Determination of age, sex and chronological collocation.

Only full adult males (as judged by fully closed epiphyses) not showing sign of advanced senescence or manifest pathological conditions were included. Sex determination was carried by cross-validating various sources of information: a) before collecting other information, sex was determined on the basis of pelvic and cranial morphology by taking into account diagnostic traits (Acsadi and Nemeskeri, 1970; Buikstra and Ubelaker, 1994; Bruzek, 2002); b) the 'archaeological sex' of the individual was considered for Orientalizing-Archaic burials, which show marked gender-based grave good differences; c) the sex determination made in previous studies was taken into account (Parise Badoni and Ruggeri Giove, 1980; Piccirilli, 1999; Bestetti, 2002; Ridolfi, 2002; Cosentino et al., 2001; d'Ercole et al., 2003a,b; Melandri, 2005); d) we developed discriminant analysis equations based on the femoral and humeral supero-inferior head diameters from individuals whom sex was reasonably certain and applied them to the rest of the sample (Sparacello, 2013). The chronological collocation of each burial was derived from previous studies based on the typologies of the grave goods (Parise Badoni and Ruggeri Giove, 1980; Piccirilli, 1999; Bestetti, 2002; Ridolfi, 2002; Cosentino et al., 2001; d'Ercole et al., 2003a,b; Melandri, 2005; Napolitano, 2012; Sparacello, 2013; Weidig, 2014; d'Ercole, Weidig, unpublished data).

Statistical analysis was conducted using Statistica 10 (Statsoft, 2011). The relationship between humeral asymmetry and the continuous variable 'Status Index' was explored through parametric and non-parametric correlations. In order to run ANOVAs, the Status Index was categorized in a stepped tier system of increasing status levels through the observation of histograms (with 5 points SI increments). The boundaries between SI categories were drawn, when possible, based on clear changes in the frequency of burials in the histograms. For example, Orientalizing-Archaic burials display a clear drop in frequency for SI above 45 (details and histograms can be found in Sparacello, 2013). Statistical significance of the differences in humeral asymmetry between categorical groups based on the Status Index were evaluated via ANOVAs and post-hoc parametric Tukey's Honestly Significant Difference tests, as well as pairwise non-parametric Mann-Whitney U-Tests.

RESULTS

Table 2 displays the results of parametric and non-parametric correlation tests between the Status Index and humeral bilateral asymmetry. A positive correlation is present only in Orientalizing-Archaic, and is highly statistically significant: individuals with higher Status Index tend to have higher humeral asymmetry (Pearson's $r=0.244$, $p<0.001$; Spearman's $rho=0.188$, $p<0.01$, Figure 2). When transforming the variables to make them normally distributed, the parametric correlation still shows significant results (Log_{10} of the Status Index on the square root of humeral bilateral asymmetry: $r=0.22$, $p<0.01$). When excluding 76 individuals for which the location of the cross section was bilaterally estimated, i.e. when length in both sides could not be measured, results remain similar ($N=141$. Pearson's $r=0.247$, $p<0.01$; Spearman's $rho=0.217$, $p<0.01$).

Insert Table 2 and Figure 2 about here

Figure 3 shows the results of an ANOVA for humeral bilateral asymmetry in Orientalizing-Archaic males with categorized Status Index as the factor (main effect $p<0.001$). Table 3 contains the sample statistics, post-hoc parametric and non-parametric pairwise comparisons between status categories. Individuals falling in the higher status category are on average more lateralized than the other subsamples (Orientalizing-Archaic males with Status Index above 45 have an average humeral bilateral asymmetry of 31.4%, while the category with Status Index between 0-15 shows an average humeral bilateral asymmetry of 19.85%), and the result is statistically significant ($p<0.01$ after multiple comparisons correction).

Insert Figure 3 and Table 3 about here

In the Hellenistic period, average male humeral asymmetry for all individuals pooled (18.6%) decreases when compared to the Orientalizing-Archaic (24.4%), and the difference is highly significant ($p<0.0001$, Mann-Whitney U-Test). No significant correlation between status and male humeral bilateral asymmetry is present (Figure 4, and Table 2). However, when dividing the sample in status categories, the ANOVA shows a significant main effect ($p<0.05$), and the 'low status' males (Status Index between 0-60) are significantly more lateralized when compared to individuals with Status Index between 60-120 (Figure 5, and Table 4).

Insert Figure 4, 5 and Table 4 about here

It should be noted that results remain similar when considering the data deriving from the Bazzano necropolis only, which has the highest number of individuals from both periods (Table 1). The correlation between Status Index and percent humeral bilateral asymmetry is present in the Orientalizing-Archaic period only (N=72. Pearson's $r=0.319$, $p<0.01$; Spearman's rho non-significant), and individuals in the highest status category have significantly higher asymmetry than the others ($p<0.001$).

DISCUSSION

In this study, we utilized a bioarchaeological research framework with the purpose of investigating shifts in military organization and power relationships. This was done by integrating behavioral inferences based on acquired skeletal properties (CSG humeral asymmetry) with archaeological information suggestive of the social standing of the individual. Both sources of information relied on assumptions whose caveats need to be discussed, but results follow the pattern expected on the basis of archaeological and historical data.

On the basis of the model of an elite army, we expected males of the Orientalizing-Archaic period to show a correlation between Status Index (as a proxy for social status) and humeral bilateral asymmetry in torsional rigidity (as a proxy for frequent weapon use). The results confirm the expectation: a positive correlation between status and humeral asymmetry is present, and is statistically significant (no correlation is present among females from the same period, Sparacello, 2013). When dividing the sample in status categories, individuals falling in the highest category show a remarkably higher, statistically significant level of asymmetry when compared to the others. The results are similar when considering the Bazzano necropolis only, strengthening the interpretation that we are assisting to a real pattern within a population.

We interpret the above pattern as a bioarchaeological confirmation that Samnites of the Orientalizing-Archaic period had elite armies. Similarly to the hoplite Greek military system, which much influenced Italic culture in the Orientalizing-Archaic period, access to military service depended on wealth and aristocratic status (Hammond, 1959; Hanson, 1989; Boatwright et al., 2004). The scenario depicted by biomechanical analsysis suggests that warrior paraphernalia were not only a display of status, but were buried with individuals that, since a young age, were destined to a military career and highly trained in the use of the Samnite weapons of choice in the Orientalizing-Archaic. This is consistent with the fact that, at the time, offensive equipment included exclusively one-handed weapons such as short swords, daggers, hatchets, maces, and especially javelins (d'Ercole and Benelli, 2004; Weidig, 2014), after which the different Samnite people were called by the Greeks ('saunion' means ‘javelin’ in ancient Greek; Tagliamonte, 2009). The same weapons are often present in infantile and juvenile graves (Cianfarani et al., 1978; Parise Badoni and Ruggeri Giove, 1980; Tagliamonte, personal communication). Conversely, results suggest that lower social strata did not normally have access to military activities, and mostly were involved in agricultural activities, which does not significantly influence humeral asymmetry (Marchi and Sparacello, 2006; Sparacello and Marchi, 2008; Sparacello et al., 2011).

Although the correlation between humeral asymmetry in torsional rigidity (J) and the Status Index is significant, it is rather weak and has a low predictive power. In addition to the noise in the model due to individual behavioral variability, and to the inherent error present in bioarchaeological methods, variability in the degree of lateralization of the humerus exists despite roughly the same amount of training in unimanual activities (Jones et al., 1977; Trinkaus et al., 1994; Haapsalo, 2000; Shaw and Stock, 2009). In addition, the Status Index was calculated as a continuous value, but social strata were probably only a few. Therefore, it would be unrealistic to expect high predictive power in a continuous numerical setting. Indeed, when categorizing the Status Index, the expected pattern emerges more clearly and results are highly significant.

Another reason for the weakness of the correlation between asymmetry in torsional rigidity and Status Index in the Orientalizing-Archaic is the possibility that some warriors, and thus high-status members of the society, were buried with little grave goods. There is ample evidence in literary sources (such as Homer’s work) that funerary treatment of warriors in Orientalizing-Archaic times depended not only on wealth and aristocracy, but also on whether the warrior had a ‘good’ or ‘bad’ death (Humphreys, 1980; Langdon, 2005). In case of ‘bad death’, an aristocratic warrior was often buried with a single item, for example a bronze razor indicating his adult age and male gender. An example of such treatment was identified for the burial 531 of the Fossa necropolis (Cosentino et al., 2001), which unfortunately was too fragmentary to be included in the study. However, this suggests that a directional bias may be present when assessing the status of individuals based on grave good richness: some high-status individuals may be erroneously included in the low-status category. The opposite is unlikely, i.e. that a low-status individual could have been buried with rich grave goods and therefore included in the high-status category. Thus, it is likely that the high-status category obtained here is a partial but reasonably non-biased depiction of the elite social strata of the Samnite society. The high humeral asymmetry and the virtual absence of non-lateralized individuals strongly suggest that unimanual activities – i.e. training in the use of weapons – were an important component of their life.

It could be questioned whether high humeral asymmetry implies a behavioral correlate, and whether weapon training is the sole explanation for asymmetry in this setting. Levels of asymmetry like the one observed among high-status Orientalizing-Archaic males are several times higher than physiological asymmetry, which is around 8-12%, (Trinkaus et al., 1994; Shaw and Stock., 2009). This must be due to frequent, highly stressful unimanual activities, as demonstrated by experimental studies (Bass et al., 2002; Ducher et al., 2005; Shaw and Stock, 2009). Churchill et al. (1996) and Rhodes and Knüsel (2005) noted that the high loading rates and intermittent character of training correspond to the pattern of activities that best stimulate osteogenic response (Burr et al., 1996, 2002; Robling et al., 2002). Experimental evidence shows that violently swinging the whole arm is the activity that mostly generates high levels of torque in humeral mid-distal shaft (Sabick et al., 2004), thus the use of mid-distal estimates of torsional rigidity appears appropriate.

Various activities have been proposed to explain high asymmetry in past populations such as hunting via atl-atl (Churchill et al., 1996; 2000; Churchill and Rhodes, 2009), and woodworking (Marchi et al., 2006, 2011; Sparacello and Marchi, 2008). Woodworking and metallurgy were most likely widespread activities in the Iron Age, and conceivably were the cause of high asymmetry for certain individuals in our samples. However, groups whose subsistence was based on agriculture in post-Neolithic times – despite the likely presence of blacksmiths and woodcutters in these samples – do not show significantly higher asymmetry than modern sedentary people, but only higher average humeral strength (Trinkaus et al., 1994; Sparacello and Marchi, 2008; Sparacello et al., 2011). It is probable that, among agriculturalists, occupations that generate high and asymmetric loads on the upper limb pertain to specialized individuals, rather than being shared, therefore have little influence on a sample's mean. On the contrary, high-status Orientalizing-Archaic individuals show a level of asymmetry (31.4%) that is significantly higher than trained medieval swordsmen (Sparacello et al., 2011), and similar to the one shown by a sample of cricket pitchers who had been training since early adolescence (Shaw and Stock 2009). Among bioarchaeological samples, only Upper Paleolithic people, whose hunting techniques were based on throwing weapons, show higher average levels of asymmetry (Churchill et al., 1996; 2000; Churchill and Rhodes, 2009). It appears that only the widespread presence and early onset of a highly repetitive and stressful unimanual activity can raise the average asymmetry to the levels seen in Orientalizing-Archaic high-status males. We believe that the most likely explanation is the early onset (pre- and peri- adolescent) and frequent practices of weapon training, given that elite social status, wealth and warlike prowess were intertwined in the Orientalizing-Archaic period (d'Ercole, 1990; Tagliamonte, 1997, 1999; Cosentino et al., 2001). Early historical accounts report that the Italic mountain dwellers of central Abruzzo were 'exceptionally strong people' who 'educated their boys in the Spartan manner' and were 'accustomed to the use of weapons' and 'defend their settlements with the sturdy right arms of their men rather than with walls' (Salmon, 1967; p 30; Tagliamonte, 1994; p 45-46). Accordingly, high lateralization is present preferentially in the wealthiest segment of the Orientalizing-Archaic population, which is the least likely to be highly infiltrated by blacksmiths and woodcutters.

Finally, the significant decrease in humeral asymmetry in males of the Hellenistic period, when weapons disappear from burials but no evidence is available for a decrease in metallurgical production or woodworking, further suggests that high asymmetry in the Orientalizing-Archaic period was due to weapon training. It should be noted that the pre- and peri- adolescent onset of unimanual training that we infer from historical and iconographic sources would address one of the problems of CSG bioarchaeological analysis pointed out by various authors (Pearson and Lieberman, 2004; Meyer et al., 2011; Jurmain et al., 2012), i.e. that activities performed later in life may not result in marked changes in periosteal bone geometry.

During the Hellenistic period, Samnites deployed large armies against Romans and fought a number of pitched battles (Salmon, 1967; Tagliamonte, 1994). Roman historians often tended to exaggerate the number of warriors in the enemy's army, either to justify the setbacks or to exalt the victories. However, the analysis of historical sources suggests that Samnites were able to mobilize thousands of soldiers (Salmon, 1967). These large armies were most likely formed by conscripts: the historian Livy reports that at a certain point all the able men were forced to 'consecrate their head to Jupiter'. Access to the army was clearly no longer exclusive to the elites, but extended on an ethnic and political basis to all the population (Tagliamonte, 1997). Thus, the passage to the standing army corresponded to a shift in its composition from wealthy elites to individuals drawn from the lower classes (Otterbein, 1970; Claessen and Skalnik, 1978).

Results of this study support the hypothesis that in Hellenistic times the warring force was no longer drawn from the higher social strata. In a context of overall significantly decreased asymmetry, no positive correlation between the Status Index and humeral bilateral asymmetry is present, and individuals with high status are no longer more lateralized than the others. This suggests that the upper limb functional adaptations of elite males were no longer influenced by early-onset, frequent weapon training. Indeed, weapons virtually disappear from the assemblages of grave goods, and a new emphasis on ornaments and the care of the body develops (d'Ercole, 1990; Copersino and d'Ercole, 2003). In contrast, Hellenistic individuals in the lowest Status Index category show the highest level of humeral asymmetry. This suggests that the lower social strata in Hellenistic times were more likely to include individuals that performed stressful unimanual activities – possibly including weapon use – than the upper social strata.

The positive correlation between status and humeral asymmetry present in the Orientalizing-Archaic period is not substituted by a negative correlation. This would be expected if a large portion of the lower class was now performing weapon training. We may speculate that conscripts were most likely individuals that entered into the army as adults, and did not train as much, or as early in life compared to Orientalizing-Archaic aristocratic scions. Moreover, although general drafts may have happened, it is likely that only a portion of the lower social strata joined the army permanently or intermittently. Most of the people were probably involved in agricultural activities that did not influence humeral asymmetry. Accordingly, the results show that individuals with low Status Index in Hellenistic times show substantial variability in humeral asymmetry, and include also highly lateralized individuals.

CONCLUSIONS

We proposed a bioarchaeological research framework jointly analyzing epigenetic skeletal properties and funerary treatment information to contribute to the study of ancient warfare and military organization. The skeletal proxy for involvement in unimanual armed conflict and/or training was high humeral bilateral asymmetry in torsional rigidity. As a proxy for the social standing of the individual, we used the Status Index based on the presence of grave good categories and the number of funerary items. Results are compatible with the model expected from archaeological, iconographic, and historical evidence. We expected that

Orientalizing-Archaic Samnites had an elite militia, where the cadets were the scion of the wealthier social strata. Accordingly, humeral asymmetry and Status Index are positively correlated, and the subsample of individual with the richest grave goods shows significantly higher asymmetry. We expected that Hellenistic Samnites developed a conscript or standing army, where the bulk of the warring force was drawn from the lower social strata. Accordingly, we found no correlation between Status Index and humeral asymmetry, and the subsample of individuals with fewer grave goods was the most lateralized.

We believe that, thanks to the employment of a large sample narrowed in a small temporal and geographical scale, the proposed research framework was able to detect a shift in military organization that happened among Samnites in concomitance with the passage to the state. Results of this study support the use of CSG analysis, when cautiously interpreted and framed in a strong bioarchaeological theoretical framework, to investigate past sociopolitical development, changes in power relationships, and warfare.

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Necropolis	Orientalizing-Archaic	Hellenistic
Alfedena	8	-
Barisciano San Lorenzo	31	-
Bazzano	72	75
Capestrano	1	5
Cinturelli	55	21
Fossa	18	30
Navelli	-	1
Peltuinum	-	4
Poggio Picenze - Varranone	5	1
San Pio - Campo Rosso	5	-
San Pio - Colli Bianchi	22	7
Total	217	144

Table 1 – Number of male individuals included in this study, by necropolis and period.

	N	Pearson's R	P-value	Spearman's R	P-value
Orientalizing-Archaic Males	217	0.244	P<0.0001	0.188	<0.001
Hellenistic Males	144	- 0.096	NS	- 0.064	NS

Table 2 – Pearson's parametric correlation and Spearman's non-parametric correlation between Status Index and percent humeral bilateral asymmetry in Orientalizing-Archaic and Hellenistic individuals. NS, statistically non-significant.

Orientalizing-Archaic Males	HUMBA			Pairwise Comparisons[1]	
	N	Mean	SD	Status Index 15-45	Status Index M 45>
Status Index 0-15	34	19.85%	13.57	NS	** (**)
Status Index 15-45	137	23.22%	14.14		** (**)
Status Index 45>	46	31.40%	17.09		
All	220	24.37%	15.06		

Table 3 – Comparison of percent humeral bilateral asymmetry among Orientalizing-Archaic male subsamples based on status categories.

[1] Post-hoc comparisons of an ANOVA with status categories as factor. Tukey's Honestly Significant Difference is provided outside of parentheses; pairwise non-parametric Mann-Whitney U-Test is provided in parentheses. Statistical significance level: NS, non-significant; *, p<0.05; **, p<0.01.

Hellenistic Males Status Index	HUMBA			Pairwise Comparisons[1]		
	N	Mean	SD	60-120	120-180	180>
0-60	42	22.77%	15.37	* (*)	NS	NS
60-120	46	15.42%	10.30		NS	NS
120-180	34	19.37%	11.78			NS
180>	22	17.03%	11.72			
All	146	18.61%	12.72			

Table 4 – Comparison of percent humeral bilateral asymmetry among Hellenistic male subsamples based on status categories .

[1] Post-hoc comparisons of an ANOVA with status categories as factor. Tukey's Honestly Significant Difference is provided outside of parentheses; pairwise non-parametric Mann-Whitney U-Test is provided in parentheses. Statistical significance level: NS, non-significant; *, p<0.05; **, p<0.01.

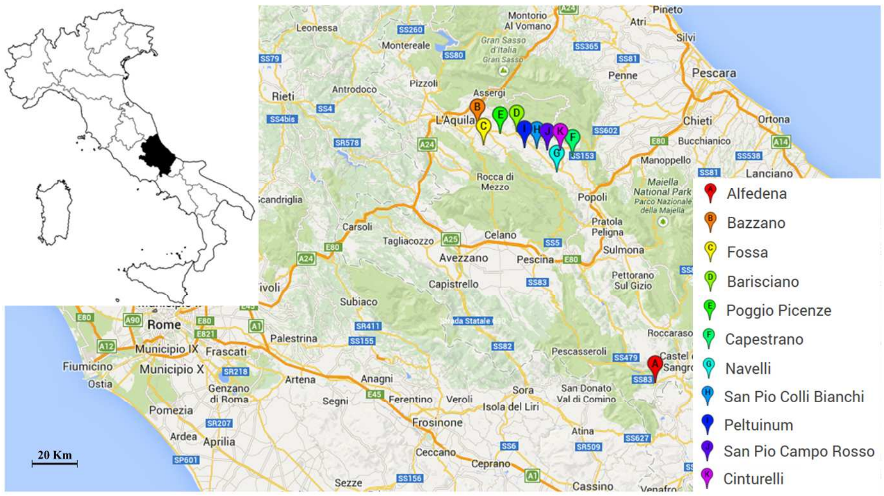

Figure 1 – Map of the modern Abruzzo region indicating the location of the necropoli included in this study.
Created with Google Maps Engine© 2014 Google Inc.
1411x1058mm (72 x 72 DPI)

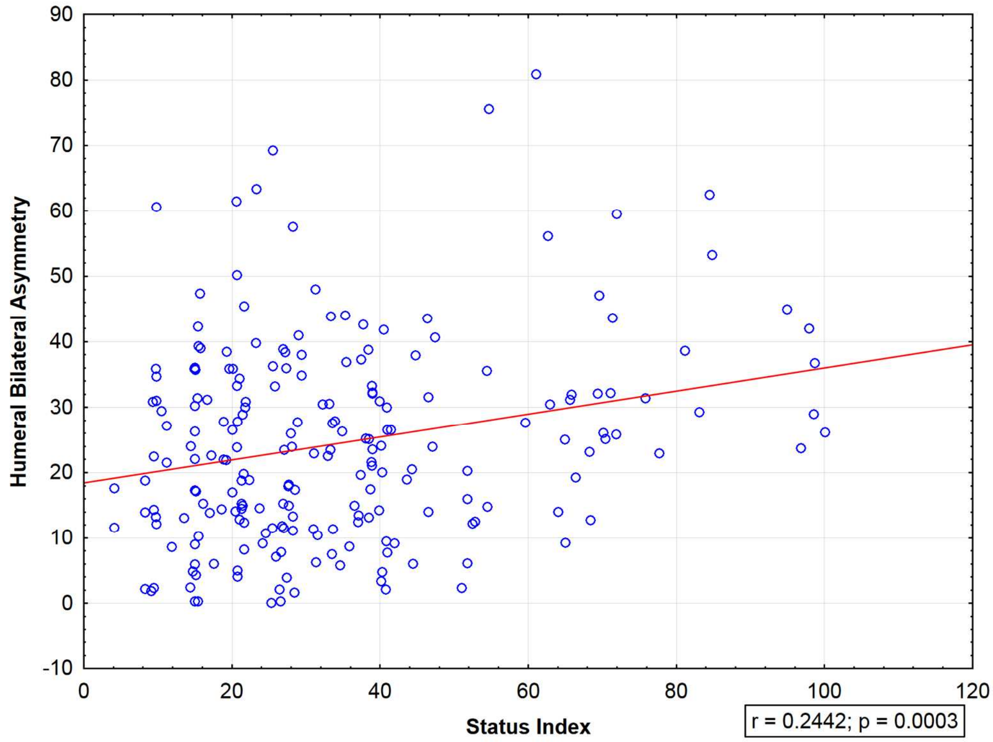

Figure 2 – Scatterplot of humeral bilateral asymmetry on the continuous value of the Status Index. Orientalizing-Archaic period males. The line represents the linear fit of the data. R and p values are based on Pearson's parametric correlation.
515x387mm (96 x 96 DPI)

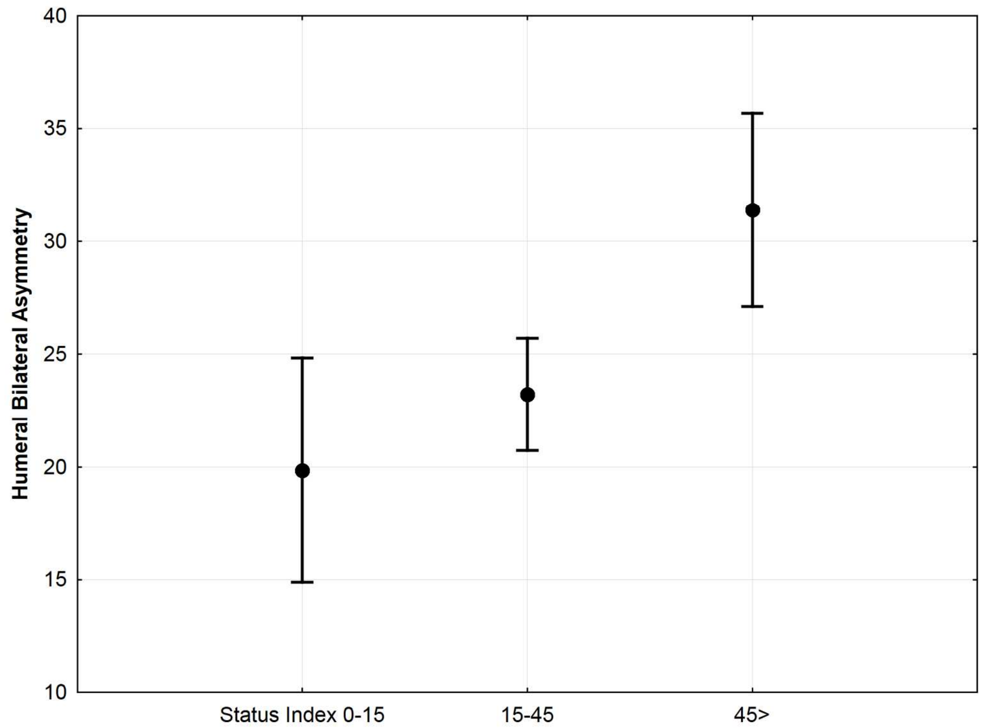

Figure 3 – One-Way ANOVA interaction plot for male percent humeral bilateral asymmetry in the Orientalizing-Archaic period, with categorical status as factor. Vertical bars denote 95% confidence intervals.
540x405mm (96 x 96 DPI)

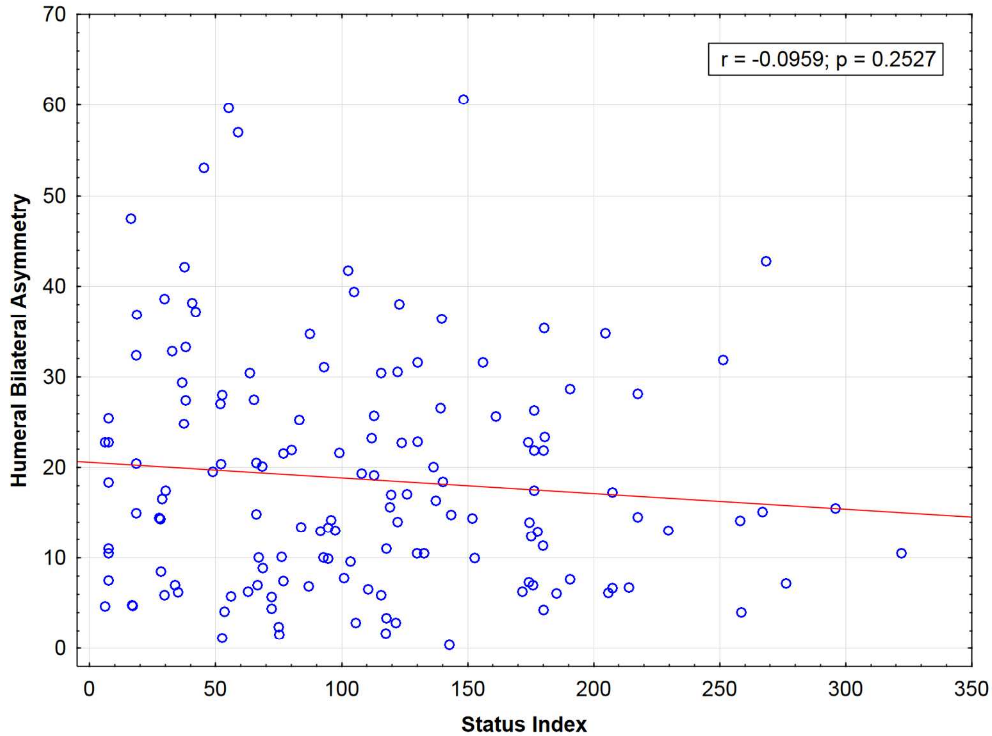

Figure 4 – Scatterplot of humeral bilateral asymmetry on the continuous value of the Status Index. Hellenistic period males. The line represents the linear fit of the data. R and p values are based on Pearson's parametric correlation.
449x336mm (96 x 96 DPI)

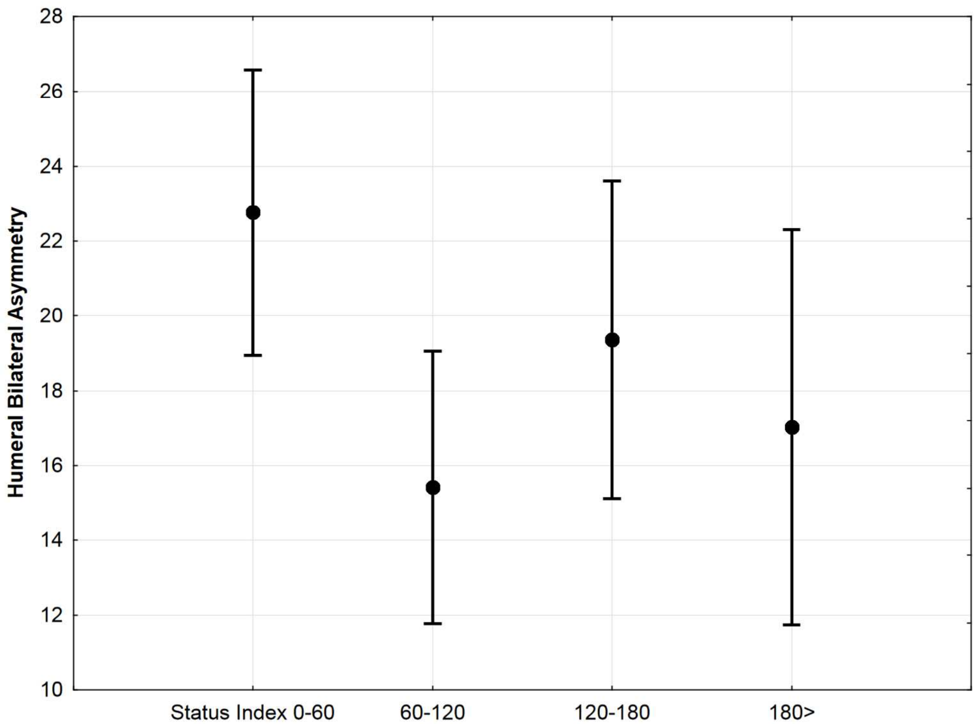

Figure 5 – One-Way ANOVA interaction plot for male percent humeral bilateral asymmetry in the Hellenistic period, with categorical status as factor. Vertical bars denote 95% confidence intervals.
441x330mm (96 x 96 DPI)

Figure 1 – Map of the modern Abruzzo region indicating the location of the necropoli included in this study. Created with Google Maps Engine© 2014 Google Inc.

Figure 2 – Scatterplot of humeral bilateral asymmetry on the continuous value of the Status Index. Orientalizing-Archaic period males. The line represents the linear fit of the data. R and p values are based on Pearson's parametric correlation.

Figure 3 – One-Way ANOVA interaction plot for male percent humeral bilateral asymmetry in the Orientalizing-Archaic period, with categorical status as factor. Vertical bars denote 95% confidence intervals.

Figure 4 – Scatterplot of humeral bilateral asymmetry on the continuous value of the Status Index. Hellenistic period males. The line represents the linear fit of the data. R and p values are based on Pearson's parametric correlation.

Figure 5 – One-Way ANOVA interaction plot for male percent humeral bilateral asymmetry in the Hellenistic period, with categorical status as factor. Vertical bars denote 95% confidence intervals.