How new methodological approaches in the study of activity markers and nonmetric skeletal traits can help in the anthropological definition of commingled inhumations

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Abstract

Classical bioanthropology analyzes skeletal markers to interpret the demography, health, and lifestyle of ancient populations. However, this becomes challenging when remains are poorly preserved or commingled. Nevertheless, it is possible to identify markers that help interpret population aspects. For this purpose, we propose using nonmetric traits of the lower limbs as indicators of habitual posture and functional adaptation to occupational activities. Our study analyzed two Sicanian populations from Sicily: Ponte della Paolina (Late Bronze Age) and Baucina (7th–5th centuries BCE). Morphological traits were recorded on adult lower limb bones, including Poirier's facet, vastus notch, and accessory articular facets. Frequencies were calculated by bone and side, and statistical association tests (Fisher's Exact and Chi-square) were applied to assess inter- and intra-population variation. Patterns consistent with prolonged crouching and foot dorsiflexion at Ponte della Paolina were found through functional analysis of trait combinations. Baucina individuals exhibited similar patterns, alongside traits suggesting more dynamic activity, such as walking on uneven terrain. The study emphasizes how useful nonmetric traits are for reconstructing postural adaptations and habitual behaviors in past populations.

Introduction

The human skeleton can exhibit many traits and variant features in the cranial and postcranial districts, known as nonmetric, or discontinuous,[1] discrete,[2] epigenetic[3] traits.

Nonmetric traits of the skeleton are anatomical variants that may affect any bone and tooth, believed to have a genetic component, influenced by epigenetic factors arising from the external environment and internal physiology.[4-6] In fact, although some of these traits can be highly influenced by environment and activity, their manifestations require a genetic predisposition.[6-8] Their incidence results from deviations from the normal skeletal development; therefore, they are not present in all individuals. For this reason, the recording method consists of evaluating their presence or absence, which can be helpful in Biological Anthropology to explore kinship between individuals and biological distance within populations, as well as in Forensic Anthropology for personal identification.[9]

The core of Biological Anthropology is the reconstruction of the biological profile of individuals, by the application of qualita-

tive and quantitative methods,[10,11] helpful for the determination of sex, the estimation of age-at-death and stature, and for the evaluation and interpretation of markers of biomechanical overload, pathologies, and nonmetric traits. The definition of the biological profile of individuals and populations can be difficult, especially in commingled remains contexts, where the low frequency of finding specimens in anatomical connection makes analysis arduous.

In this context, the purpose of the present study is to provide a combined interpretation of nonmetric traits associated with repetitive physical activity and to reconstruct the habitual postures the individuals assumed daily, which are likely related to occupational activity. The aim is to comprehend the daily life of individuals found in protohistoric commingled contexts, specifically related to two Sicanian communities recovered in two different Sicilian necropolises. Given the existing evidence that these populations engaged in agro-pastoral subsistence activities and the high frequency of nonmetric traits found per category, we sought to evaluate whether an integrated analysis of multiple nonmetric traits could enhance the anthropological interpretation of behavior and activity patterns.

Materials and Methods

The study has been conducted on two Sicanian communities recovered from the necropolis of Ponte della Paolina (Ragusa, Sicily, Italy) and the necropolis of Baucina (Palermo, Sicily, Italy), respectively on the Eastern and Western sides of Sicily (Figure 1a) and representing two consecutive chronological phases (Early Bronze Age and Iron Age). Both communities have been found within an artificial cave tomb, a typical commingled burial related to Sicanian tradition.

Archaeological context of Ponte della Paolina

The necropolis of Ponte della Paolina is located on a hill near the southern coast of Ragusa, Sicily. In 1977, during the excavation campaign conducted by the Superintendency of Cultural Heritage of Siracusa, a complex of three artificial cave tombs was discovered. Two of these tombs, relatives to commingled burials dated to the Early Bronze Age, have been explored. Specifically, the osteological sample analyzed in this study comes from "Tomb 2" (Figure 1c), where the human remains were deposited without an apparent order.[12] This disorganized arrangement is likely due to a reuse of the tomb, which was probably reserved for individuals belonging to the same family or clan.[13,14] Anthropological analyses conducted by the authors resulted in a Minimum Number of Individuals (MNI) of 34 non-adults (based on mandibles) and 45 adults (based on maxillary bones and confirmed by left talar bones), for a total of 79 individuals.

Archaeological context of Baucina

The necropolis of Baucina is located on a hilltop between the Milicia and San Leonardo rivers, approximately 15 km from the Tyrrhenian Coast, and between Mount Falcone (695.1 m above sea level) and Mount Carrozza (745.9 m above sea level).[15] The excavation essay conducted in 2014 extended ca. 45 m^2 along the southern slope of Mount Falcone and revealed fifteen burials arranged next to each other without particular order (Figure 1b). The types of tombs represented are as follows: a quadrangular artificial cave tomb (US 18); within *kalypteres*; an *enchytrysmòs* tomb; ground burial; and a primary cremation in ground burial. The coexistence of several burial types, including those of Greek tradition (monosome burials and incineration with grave goods), the presence in the grave goods of Greek ceramics and pottery with painted decoration, and the presence of a bronze coin inside the artificial cave tomb, exclusively Greek in use, makes it possible to ascertain the existence of contacts and relations between Greeks and indigenous peoples, with the acquisition of forms of burial different from the Sicanian traditional ones. Moreover, numerous fragments of Punic amphorae also testify to trade relations with the coastal cities of Solunto and Panormo.

The multidisciplinary study of grave goods, burial typology, and ^{14}C dating made it possible to estimate the occupation of the territory between the 7^{th} – 5^{th} centuries BCE.[15-17]

The opening of the partially artificial cave tomb (US 18) during the last excavation campaign,[16] brought to light commingled human skeletal remains belonging to a Sicanian population. US 18 has been looted at different times,[16] and these actions caused the

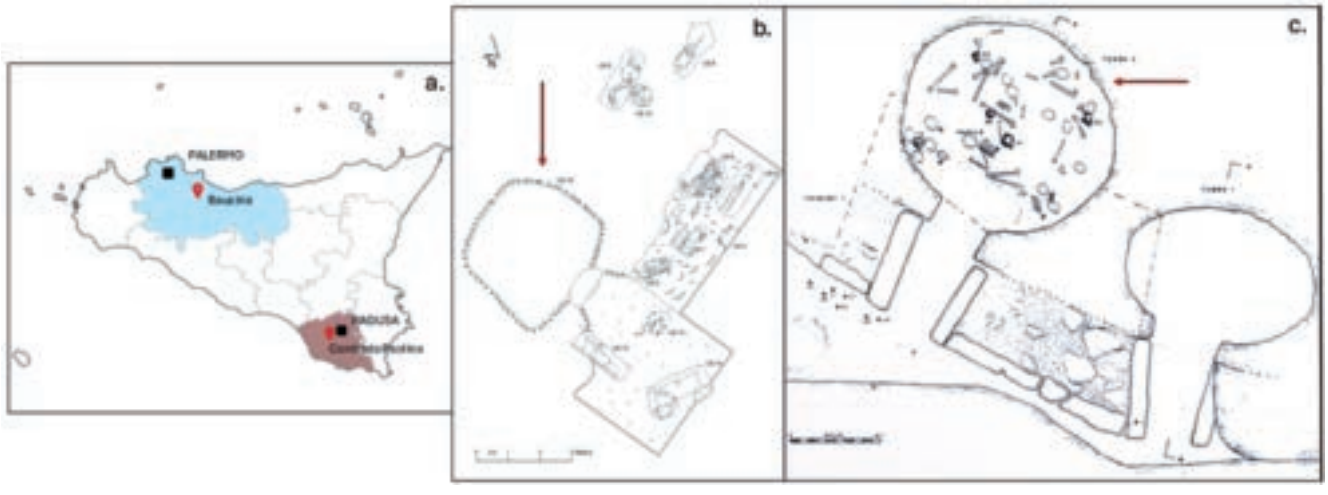

Figure 1. a) Geographic map of Sicily; b. Topographic map of the archaeological site of Baucina (red arrow US 18). Modified from Belvedere *et al.* (2017); c) Topographic map of the archaeological site of Ponte della Paolina (red arrow Tomb 2); modified from Procelli 1981.

disarticulation and fragmentation of the skeletons, therefore it influenced the bio-anthropological analyses.

The study of the entire skeletal sample was conducted at the Laboratory of Anthropology "LabHomo" of the University of Palermo (Italy). Anthropological analyses of the sample results in a MNI of 59: 50 adult individuals, based on the left 3rd metatarsal and right 4th metatarsal, and 9 non-adult individuals based on the ulnar proximal epiphysis.

Methods

In this study, we focused on adult bones of the lower appendicular skeleton, specifically the femur, tibia, patella, talus, and calcaneus. No exclusion criteria were applied regarding adult bone preservation or completeness: all available elements, including isolated and fragmentary specimens, were examined. For each anatomical bone element, the presence or absence of the selected nonmetric traits (see following paragraph) was recorded, considering exclusively those bone regions where such traits can be reliably observed. Trait frequencies were then calculated within the adult samples of both populations.

Calcaneal entheseal changes were recorded following the method of Mariotti *et al.*[18]

Additionally, a statistical analysis was conducted as an association study. Specifically, Fisher's Exact Test was employed to assess potential differences in the presence or absence of each nonmetric trait based on two factors: i) the occurrence of symmetry or asymmetry between the right and left sides within each population, and ii) potential differences in trait expression between the two populations.

Finally, the Chi-square test was applied to evaluate possible differences in the degree of calcaneal entheseal stress, considering both lateral variation and marginal differences between the two populations.

Selected nonmetric traits

Poirier's facet

It is a nonmetric trait generally defined as a lateral extension of the articular surface of the femoral head toward the femoral neck (Figure 2a).[19,20] When present, the facet is smooth with defined and raised lateral margins.[21] The etiology of Poirier's facet is still unknown, but scholars agree to attribute its presence as a result of mechanical pressures, causing repeated contact between the femoral head-neck junction and the acetabular rim.[21-27] Therefore, this facet is considered an activity indicator, involving functional movements such as squatting,[28] sitting cross-legged and horseback riding,[25,29,30] habitual abduction and flexion during locomotion,[31] thigh extension during running and walking downhill.[24]

Vastus notch

It is a small concavity located on the superolateral side of the patella (Figure 2d).[20,32] Although rarely reported in bioarchaeological studies, there is a general agreement that its presence results from repetitive knee flexion.[32-35] This motion leads to continuous contraction of the vastus lateralis muscle, generating sustained tension that produces a smooth-edged impression[20,33] on the bone. Vastus notch may present as a slight or a deeply marked

Figure 2. a) Poirier's facet (white arrow) in a left femur, anterior view; b) lateral squatting facet (white arrow) in a left tibia, anterior view; c) lateral and medial squatting facets (white circles) and trochlear extension (white arrow) in a left talus, superior view; d) vastus notch (white arrow) in a right patella, anterior view; e) Achilles tendon with degree 1a of entheseal change in a left calcaneus, posterior view; f) Achilles tendon with degree 3 of entheseal change in a left calcaneus, posterior view. All images with 1 cm scale bar.

concavity,[33] associated with activities such as squatting, kneeling, and resting position.[35]

Squatting facet

Squatting facets are bony modifications that can occur on the talus and distal tibia (Figure 2b,2c), resulting from bone remodeling due to the pressure during hyperdorsiflexion of the ankle, caused by squatting positions. The anterior surface of the tibia abuts the dorsal portion of the talar neck when the knee and foot are hyperdorsiflexed. It is possible to distinguish between medial and lateral squatting facets. Regarding the tibia, the squatting facet is recorded as present when there is a disruption in the usually straight anterior margin of the distal tibia.[36] Thomson[37] described talar squatting facets as small oval or round-shaped smooth facets, on the lateral or medial upper surface of the talar neck.[38]

Trochlear extension

It represents a feature that can occur on the upper medial or lateral surface of the talar trochlea,[38] extending as a smooth osseous structure from the trochlear surface towards the talar head (Figure 2c).[6] Trochlear extension is generally associated with tibiotalar rubbing during plantarflexion and dorsiflexion of the ankle.[6,38]

Results

The skeletal assemblage from Ponte della Paolina necropolis includes 127 femora, 76 patellae, 79 tibiae, 87 tali, and 84 calcanei; while that from Baucina comprises 49 femora, 51 patellae, 47 tibiae, 68 tali, and 54 calcanei. These counts include both complete and fragmentary bones. However, the number of elements suitable for analysis was reduced because each nonmetric trait occurs in a specific, well-defined anatomical region of the bone, not always preserved or readable. Consequently, only the bones in which areas of interest for the presence/absence of the selected nonmetric traits were preserved, were considered (see Table 1).

General bilateral consistency in nonmetric trait expression is revealed by frequencies and statistical analysis, with only slight variations between the left and right sides and between the two assemblages.

The most frequent trait recorded is the lateral squatting facet in the tibia and in the talus, amounting to 87.0% left and 80.8% right in Ponte della Paolina and 64.3% left and 74.3% right in Baucina.

The Fisher's Exact Test showed no statistically significant asymmetry between sides (Table 1), except for the patellar vastus notch, where a p value of 0.05 was observed in both samples, indicating a slight directional variation.

Concerning the marginal distribution (Table 2), a statistically significant difference is observed for the medial trochlear extension of the talus ($p = 0.03$), which is more frequent in Baucina than in Ponte della Paolina.

All other traits yielded p values > 0.05, indicating no statistically significant differences in the distribution of nonmetric traits between the two populations.

Recording of calcaneal entheseal changes (Table 3) results in major frequencies of degrees 1c and 2 for Ponte della Paolina and degrees 2 and 3 for Baucina. Statistical analysis shows differences

Table 1. Number and frequency of nonmetric traits for each bone considered for both populations. (OBS = observed; NON OBS = non observed; TOT = total). Results of Fisher's Exact test p values for side differences.

Ponte della Paolina											
		Left					Right				
Bone	Nonmetric trait	OBS		NON OBS		TOT	OBS		NON OBS		TOT	Fisher
		n	%	n	%		n	%	n	%		p value
Patella	Vastus notch	9	23.7	29	76.3	38	17	47.2	19	52.8	36	0.05
Femur	Poirier's facet	13	54.2	11	45.8	24	12	66.7	6	33.3	18	0.53
Tibia	Medial squatting facet	6	30.0	14	70.0	20	2	9.1	20	90.9	22	0.12
Tibia	Lateral squatting facet	20	87.0	3	13.0	23	21	80.8	5	19.2	26	0.71
Talus	Medial squatting facet	14	34.1	27	65.9	41	9	25.0	27	75.0	36	0.46
Talus	Lateral squatting facet	27	64.3	15	35.7	42	26	74.3	9	25.7	35	0.46
Talus	Medial trochlear extension	13	31.7	28	68.3	41	12	33.3	24	66.7	36	1
Talus	Lateral trochlear extension	22	51.2	21	48.8	43	18	48.6	19	51.4	37	1
Baucina											
		Left					Right				
Bone	Nonmetric trait	OBS		NON OBS		TOT	OBS		NON OBS		TOT	Fisher
		n	%	n	%		n	%	n	%		p value
Patella	Vastus notch	2	8.7	21	91.3	23	9	33.3	18	66.7	27	0.05
Femur	Poirier's facet	4	40.0	6	60.0	10	5	55.6	4	44.4	9	0.66
Tibia	Medial squatting facet	5	38.5	8	61.5	13	6	42.9	8	57.1	14	1
Tibia	Lateral squatting facet	11	84.6	2	15.4	13	11	78.6	3	21.4	14	1
Talus	Medial squatting facet	6	25.0	18	75.0	24	11	42.3	15	57.7	26	0.24
Talus	Lateral squatting facet	19	79.2	5	20.8	24	20	80.0	5	20.0	25	1
Talus	Medial trochlear extension	14	56.0	11	44.0	25	13	52.0	12	48.0	25	1
Talus	Lateral trochlear extension	7	28.0	18	72.0	25	9	36.0	16	64.0	25	0.76

OBS, Observed; NON OBS, Non Observed.

between the two assemblages (Table 3), with significant differences in stress values concerning the left side and the overall stress degree of each population.

Discussion

This study was performed to analyze the prevalence of various nonmetric traits of the lower appendicular bones among individuals related to two Sicilian protohistoric populations. The examined traits are related to physical activity performed by living individuals or to postures they assumed during the day, related to economic activity.[6] The purpose of this paper was to evaluate whether the presence of multiple nonmetric traits could be an additional method of evaluation, compared to the usual bioanthropological investigations (e.g., entheseal changes), especially in reference to commingled burial contexts.

Most traits are present in at least 40% of observable elements, indicating a consistent pattern of squatting- and crouching-related features in the expression of nonmetric traits. The most frequent squatting facets on the tibia and talus involved prolonged lower limb flexion and repetitive ankle dorsiflexion, movements linked to habitual kneeling, squatting, or walking up and down hills. This pressure on the tibio-talar joint is also reflected in the high percentage of lateral and medial trochlear extension in both populations, with a greater frequency of the lateral one in Ponte della Paolina and the medial one in Baucina. The assumed posture of squatting and/or crouching could be testified by the frequencies of Poirier's facet (54.2% left and 66.7% right for Ponte della Paolina; 40.0% left and 55.6% right for Baucina) and vastus notch (23.7% left and 47.2% right for Ponte della Paolina; 8.7% left and 33.3% right for Baucina), the first related to deep hip flexion[24,25,28-30] and the second to contraction and flexion of the knee,[32-35] movements that could be associated with each other. According to the results of Fisher's Exact test, there is a slight asymmetry for the vastus notch ($p = 0.05$) but a bilateral symmetry in the expression of the other

Table 2. Results of Fisher's Exact test for marginal distribution comparing trait frequencies between the two populations.

Marginal distribution (left + right)						
		Baucina		Paolina		Fisher p value
Bone	Nonmetric trait	OBS	NON OBS	OBS	NON OBS	
Patella	Vastus notch	11	39	26	48	0.17
Femur	Poirier's facet	9	10	25	17	0.54
Tibia	Medial squatting facet	11	16	8	34	0.09
Tibia	Lateral squatting facet	22	5	41	8	1
Talus	Medial squatting facet	17	33	23	54	0.77
Talus	Lateral squatting facet	39	10	53	24	0.26
Talus	Medial trochlear extension	27	23	25	52	0.03
Talus	Lateral trochlear extension	16	34	40	40	0.07

OBS, Observed; NON OBS, Non Observed.

Table 3. Results and frequencies of the application of the Mariotti *et al.* method (2007) for the Achilles tendon insertion (L=left; R=right). Results of the application of the Chi-square test for bone side (left and right) and marginal (left + right) between the two assemblages.

Ponte della Paolina						
Achilles tendon	L		R		Total	
Degree	n	%	n	%	n	%
1a	1	3.13	2	7.14	3	14.71
1b	9	28.13	6	21.43	15	8.82
1c	11	34.38	7	25.00	18	11.76
2	6	18.75	8	28.57	14	26.47
3	5	15.63	5	17.86	10	38.24
Total	32	100.00	28	100.00	60	100.00
Baucina						
Achilles tendon	L		R		Total	
Degree	n	%	n	%	n	%
1a	4	19.05	1	7.69	5	14.71
1b	1	4.76	2	15.38	3	8.82
1c	4	19.05	0	0.00	4	11.76
2	6	28.57	3	23.08	9	26.47
3	6	28.57	7	53.85	13	38.24
Total	21	100.00	13	100.00	34	100.00
Chi-square p value	0.046		0.11		0.013	

traits ($p > 0.05$). This lateral variation may suggest habitual postural asymmetry or preferential limb use.

Inter-population comparisons demonstrate statistically significant differences only for the medial trochlear extension of the talus ($p = 0.03$), which is more frequent in Baucina, and may be linked to the topographical context,[15,16] a hilltop settlement implying greater engagement in uphill and downhill locomotion.

This interpretation is further supported by analysis of Achilles tendon entheses. Both populations exhibit a predominance of moderate-to-severe entheseal changes (degrees 2-3), reflecting significant mechanical stress of the area. However, according to the Chi-square test, statistically significant interpopulation differences between the two assemblages are present ($p = 0.046$ for the left side, $p = 0.11$ for the right side, and $p = 0.013$ for the combined data), suggesting greater stress in Baucina. This pattern is consistent with the higher frequency of degree 3 changes (Figure 2f) and the presence of inferior calcaneal spurs in Baucina. Since calcaneal bone spurs may result from repetitive vertically oriented forces,[39] their occurrence points to greater locomotor demands, possibly due to movement over irregular terrain or long-distance walking associated with daily mobility and trade networks. This interpretation is consistent with the settlement's hilltop location and the evidence of trade with Greek and Punic civilizations that inhabited the area.[16,17] Mann and Hunt[36] report that not all squatting facets develop as a direct result of squatting, but that other physical activities, such as running and climbing, result in dorsiflexion of the foot toward the knee. Furthermore, there is a documented correlation between calcaneal bone spurs and foot pronation,[39] a movement in which the ankle rotates inward to absorb shock during walking or running. This movement could also be associated with the presence of talar trochlear extension which shows a statistically significant difference between the two populations, being more frequent in the Baucina sample.

In contrast, the lower entheseal degrees in Ponte della Paolina and the absence of calcaneal spurs may reflect more static or repetitive postural stress, such as prolonged squatting or kneeling during sedentary activities.

Although there is no strong bilateral asymmetry, the combined frequencies point to a habitual asymmetric squatting posture, with the left limb flexed and weight-bearing, and the right leg partially extended with the heel raised. This configuration is consistent with the distribution of Poirier's facet and vastus notch, more frequently expressed on the right side, and with calcaneal stress asymmetry, where right-side entheses exhibit higher-grade changes. These results support the reconstruction of a recurring postural schema that combined everyday labor and subsistence practices with both static and dynamic stress patterns.

Conclusions

The populations examined in this study belong to Sicanian communities who inhabited their settlements during the Bronze Age (Ponte della Paolina) and Iron Age (Baucina). This research aims to provide an integrated interpretation of nonmetric traits of the lower limb associated with repetitive physical activity, to reconstruct the habitual postures adopted in daily life by individuals. Particular attention was given to forced and repeated positions that can lead to specific alterations of joint surfaces.

Morphological and statistical analysis results indicate that the two populations were homogeneous, highlighting a common biomechanical adaptation and postural repertoire. This suggests a habitual seated or resting posture characteristic of prehistoric or traditional cultural contexts, where individuals may have frequently assumed squatting or kneeling positions during daily activities like food preparation, tool use, or social interaction. This condition aligns with the domestication of plants and animals as well as agricultural and pastoral Sicanian subsistence activities.[40] However, Baucina's elevated location and interactions with external trade systems may be responsible for the variation in calcaneal stress patterns, which reflect environmental and behavioral specificities. It is possible that, over time, mechanical stresses associated with repetitive postures helped to differentially express nonmetric skeletal traits, providing information about behavioral patterns within protohistoric communities. To achieve more reliable statistical validation, future studies should broaden the comparative framework to include larger and non-commingled samples. The authors emphasize the importance of examining nonmetric traits across multiple skeletal elements, as only a holistic approach allows for an accurate reconstruction of habitual posture and for differentiating between static and dynamic activities. A crucial component is the methodical assessment of asymmetry. While prior research has often reported nonmetric trait frequencies without additional interpretation, the present study highlights the importance of critical analysis and comprehension. From a biocultural perspective, these results demonstrate how the skeletons of past individuals are marked by repetitive motions, turning bones into archives of embodied memory.

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