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Weighing premonetary currency in the Iberian Iron Age

Thibaud Poigt

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Gifts, Goods and Money

Comparing currency and circulation
systems in past societies

edited by

**Dirk Brandherm, Elon Heymans and
Daniela Hofmann**

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Weighing premonetary currency in the Iberian Iron Age

Thibaud Poigt

Abstract

While the practice of weighing is well attested in the archaeological record from later prehistoric Iberia, the context of this practice remains uncertain. Several examples show weight standardisation in the composition of hoard assemblages, both of undamaged and fragmented objects, but we rarely can relate the metrological standards identified in such assemblages with contemporary scale weights. Through a study of the weights discovered in the necropolis of El Cigarralejo (Mula, Spain), it is possible to demonstrate the high level of technical sophistication in the conception of Iberian scale weights and the variation between metrological standards from neighbouring sites. These observations lead us to reflect on the potential role of weighing for conducting transactions in a premonetary currency and the use of metrological standards for their normalisation.

Keywords: weights, Iberia, metrological system, photogrammetry

Résumé

Peser la pré-monnaie à l'Âge du Fer en Ibérie

Si l'usage de la pesée est bien attesté par le registre archéologique pour la péninsule Ibérique protohistorique, ses contextes d'utilisation demeurent incertains. Plusieurs exemples montrent l'utilisation de la normalisation pondérale dans la constitution de dépôts d'objets, entiers ou fragmentés, mais peu des étalons métrologiques repérés peuvent être rapprochés des valeurs des poids de balance contemporains. A travers l'étude de cas des poids découverts dans la nécropole d'El Cigarralejo (Mula, Espagne), nous montrons ici la haute technicité entrant dans la conception des lots de poids de balance ibériques et l'hétérogénéité du partage d'étalons métrologiques entre sites voisins. Ce constat mène à s'interroger sur le rôle possible de la pesée dans les pratiques de contrôle de moyens de paiement prémonétaires et l'utilisation de standards métrologiques pondéraux pour leur normalisation.

Mots-clés: poids, Ibérie, système métrologique, photogrammétrie

Zusammenfassung

Das Abwiegen premonetärer Zahlungsmittel in der iberischen Eisenzeit

Auch wenn die Praxis des Wiegens durch archäologische Funde für die Frühgeschichte der Iberischen Halbinsel eindeutig belegt ist, bleibt ungewiss, in welchen Kontexten sie ausgeübt wurde. Mehrere Beispiele belegen eine Gewichtsstandardisierung in der Zusammensetzung von Hortfunden, sowohl von unbeschädigten als auch von fragmentierten Objekten, aber nur wenige der metrologischen Standards, die in diesen Fällen identifiziert wurden, können mit zeitgleichen

Wiegeinstrumenten in Verbindung gebracht werden. Eine Untersuchung der Gewichte, die in der Nekropole von El Cigarralejo (Mula, Spanien) entdeckt wurden, belegt den hohen technischen Stand, welcher der Konzeption der iberischen Gewichtssysteme zugrunde liegt, sowie die Variabilität zwischen metrologischen Standards benachbarter Fundorte. Hieraus ergeben sich Fragen zur möglichen Rolle des Wiegens in prämonetären Währungssystemen und für die Verwendung metrologischer Standards in ihrer Normierung.

Schlüsselwörter: Gewicht, Iberien, metrologisches System, Photogrammetrie

Introduction

The purpose of this paper is to reflect on the link between currency, trade and weighing, based on a case study of a set of ten weights found in grave 200 at El Cigarralejo (Mula, Murcia), published originally by Cuadrado (1964). It dates to the late fifth or early fourth century BC, a period during which the Iberians did not use coinage, but were in contact with Mediterranean merchants (essentially Carthaginians and Greeks) who used monetary systems. Indeed, even if the first coins appeared relatively early in the Iberian Peninsula (fifth to fourth centuries BC, from Greek and Punic cities), the indigenous Iberians only adopted a monetary system during the third century BC, a date that corresponds to the first local coinage (García-Bellido 2011: 133; Gorgues 2010: 69).

Weighed metal was used during Antiquity and this practice is quoted for instance by Aristotle, even if we have to be careful to associate these mentions with the people that we are dealing with here:

For the natural necessities are not in every case readily portable; hence for the purpose of barter men made a mutual contract to give and accept some substance of such a sort as being itself a useful commodity that was easy to handle in use for general life, iron for instance, silver and other metals, at the first stage defined merely by size and weight, but finally also by impressing on it a stamp in order that this might relieve them of having to measure it; for the stamp was put on as a token of the amount (Politics, I, 1257a, translated by H. Rackham).

Metal represents a universal symbol during later prehistory as an essential raw material. Copper, gold, tin and later iron had a prominent role in many European and Mediterranean exchange networks. Scholarship has emphasised the part played by metal in a wide range of economic, political and social processes, such as the work of Van Driessche about the slow transition from premonetary standards made of metal to the bronze coinage in Greece during the Bronze and Iron Ages (Van Driessche 2009). For these reasons, it would not

be surprising if the principal medium of currency before the appearance of coinage was metal. Nevertheless, other materials could also have fulfilled this function, for instance salt, textiles or cattle.

The aim here is not to discuss the material form of premonetary currency, but to debate the abstract concepts that this practice involves. In the absence of an independent measure for the value of the exchanged goods, the latter is only determined in function of common equivalences, shared by actors of trade. For example, during the Mycenaean period it seems that a bull equals five sheep (Van Driessche 2009: 31), a current equivalence applied in barter, without use of an independent means of measuring.

Nevertheless, the determination of a means of payment destined to facilitate trade implies agreement about value and measuring quantity. If an animal can be considered as one unit, the matter is different with bulk goods or raw materials, which need more specific quantification. In that case, talking about premonetary currency implies talking about a system of measurement as a means to exercise control over the quantities involved in the process. Weighing represents one way to measure products and appears to be the most efficient for some of them, such as metal, salt or even textiles. But even if it is weights that concern us here, we also have to keep in mind the existence of measures of length and volume. Metrological concepts can be applied to currencies as well: the need to define a norm, to create units and potentially fractions and multiples, as will be demonstrated below.

The practice of depositing weighing instruments in graves in the Iberian Peninsula spread particularly between the fifth and third centuries BC, essentially along Iberia's Mediterranean seaboard (Poigt 2015a: 136) (Figure 1). The same phenomenon can be observed in other geographic areas and periods, like the central European Bronze Age (Pare 1999: 510). It seems unlikely that the deposition of tools in graves is a consequence of a change in weighing practice: the appearance of weights in tombs is not associated with a change of weighing instruments or the metrological system, even if data available for the latter have to be used with care. We probably have to attribute their appearance in the funerary record to changes in how this activity was represented in funerary ritual.

Indeed the typology of the Iberian weights, made of copper alloy or lead, has been well known since the beginning of the twentieth century, primarily through the works of I. Ballester (1930). Mostly, we are dealing with perforated cylindroids, with few variations. They can be of cylindrical or discoid shape,

sometimes without perforation.¹ In rare cases, one of the faces is inscribed. These marks could be linked to a metrological system in some instances (e.g. Syrian *shekel*, Athenian *drachma* or double-*drachma*). In an article of 2003/04, I. Grau Mira and J. Moratalla Jávega suggested a Phoenician origin for the morphology of Iberian weights, using as an example two pyramidal perforated weights from Kerkouane (Tunisia), contemporary with those from the Iberian area (Grau Mira and Moratalla Jávega 2003/2004: 42).² However, along the western seaboard of the Iberian Peninsula we find cylindroid weights with a central perforation from the Bronze Age onwards, as shown by the work of R. Vilaça (2003; 2011). Weights of this type are present in a large part of Iberia (Figure 1). However, the distribution of the weighing instruments in the Iberian Peninsula shows empty zones, which leads us to believe that there are still many artefacts to identify.

Among the 268 weights identified for Spain and Portugal in the Bronze and Iron Ages (at the time of writing this paper), the heaviest weighs 493.3g (La Bastida de les Alcuses, Moixent, Valencia) and the average mass equals 47.1g. But more research is certainly necessary to verify that heavier weights of different types and/or different materials have not been missed. Evidence for 'heavy weighing' could completely change the scenario derived from the archaeological data currently available and might alter our perception of how trade was conducted during this period.

From comparison to measurement

To clearly understand the problems concerning weighing practice and its possible application to the definition of value in a premonetary economy, it is important to explain some points of the cognitive context underpinning its development. Firstly, the appearance of weighing is the answer to a need, which is not universal. As stated above, the Iberian Peninsula is at the centre of complex trade networks, which influence this practice. And secondly, we will give a brief overview of our current knowledge about the phenomenon of premonetary currency in the study area.

Why weighing? How to weigh?

The practice of weighing can involve a wide range of measuring devices. The need to measure can result from many factors and relate to different properties, involving mass, length, or capacity. However, we have to distinguish two different approaches: the direct comparison of data and the calculation of an absolute value with respect to a reference scale.

¹ Referring to the typology introduced in the abstract of my PhD project (Poigt 2015b).

² These weights are not pictured in the original publication.

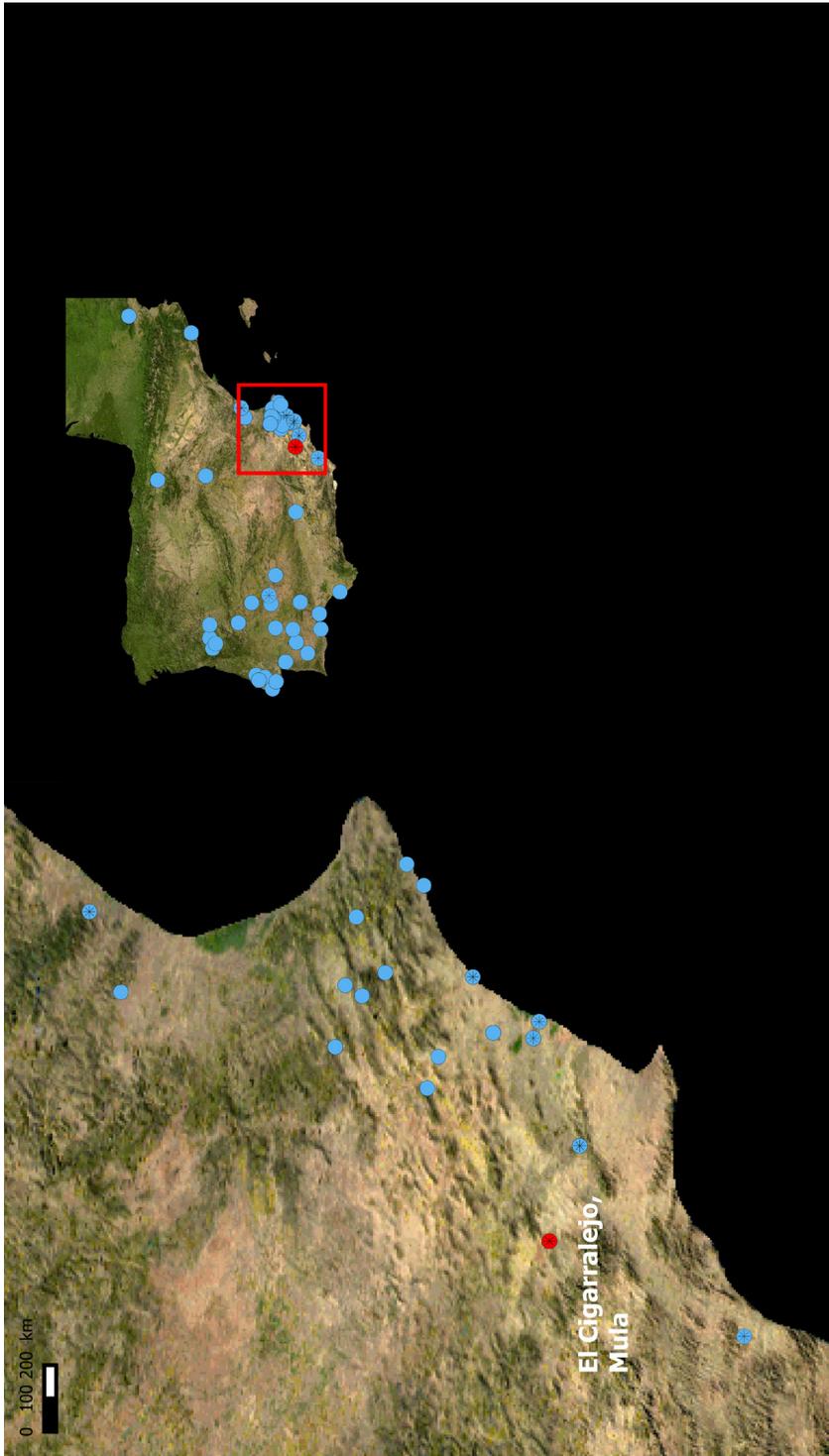


Figure 1. Distribution of weighing instruments in the Iberian Peninsula.

This is to say that when it comes to weighing, it is in the first instance a comparison and, from this point of view, it is quite intuitive and universal. It consists in comparing the mass of one product with another, to determine the heaviest one and the lightest one. Where weighing involves actual ‘measurement’ it instead addresses the need to attribute a numeric value to analogical data not recordable intuitively. This type of measure depends necessarily on a pre-established system and thus on the existence of a metrology and a norm. The creation of a weighing norm requires the definition of a standard, a quantity of product *lambda* becoming the reference of the system. Subsequently, all the measurements are compared to this standard. To facilitate the calculation, set multiples and fractions are generally organised around this unit of reference. Like all norms, it has to be imposed by an authority. This fact is important because, in consequence, a ‘normative’ weighing has its limits, which are conditioned by the influence of the authority which implements it.

We can broadly distinguish two types of weighing. One is what we will refer to as ‘heavy weighing’, which permits the measuring of great quantities of material and which necessitates large scales for being effective. Concerning Iberian period, at the moment there is no archaeological evidence for such a practice. The weights are light, always below 500g (the great majority is below 200g), and the average diameter of the scale pans that have been identified approximates ten centimetres. We can thus refer to the corresponding practice as ‘precision weighing’. Even if it remains difficult to define a clear boundary between these two types of weighing practice, the difference greatly influences possible usage.

The distinction between ‘heavy’ and ‘precision’ weighing, and the existence or non-existence of a reference standard, are fundamental issues in the study of ancient metrologies. They entirely condition the weighing metrology applied, which cannot be understood without including these criteria in the reasoning. Indeed, the manufacture of a weight, in line with the nature of its function, necessarily depends on a combination of the following factors: establishment of the norm, cultural traditions and intended uses.

The practice of weighing implies the mastering of several abstract concepts. First, mass has to be defined as an invariable value in time and space. This means that an object always possesses the same mass and this remains true everywhere on the surface of the earth.³ This is not to say that later prehistoric people could not have observed and understood these concepts through practical experience. Even today, the modern definitions of ‘weight’ and

³ The mass (calculated in grams for the metric system) is an invariable value. This unit differs from the weight, which depends on the gravity, calculated in newtons.

'mass', only conceptualised since the seventeenth century AD, are generally not completely distinguished from each other. Furthermore, the adoption of a standard, even the simplest, requires an understanding of basic arithmetic concepts like addition and subtraction, or, in the case of complex metrological systems, of multiples and fractions. Knowledge of this type of abstract concept was probably not widespread during the Bronze and Iron Ages, but would have been a privilege of well-educated and high-status individuals. This means that a part of the population probably could not understand the more complex weighing operations, an even harder task where a written medium was lacking.

As pointed out above, any metrology depends on a standard validated by an authority. By the same token, a metrological system will not have any value outside the sphere of influence of the authority that guarantees it, which can range from the nuclear family to the international scale. The system will be of no consequence for the exchange of goods and the capacity for trade outside of this sphere of influence. No such systems existed at an international level before the development of the metric system. Even in France in 1795, before the adoption of the metre and its derivatives, there were several hundred different metrological systems (Palaiseau 1816).

Apart from the above, another necessary condition for making scale weights is the capacity to model a material in order to give it the required mass and form. Since the Palaeolithic, humans have modified natural materials to create forms adapted to their needs. However, to obtain a specific mass, numerous steps of control are required during the manufacturing process. This can be relatively easy when using stone as a material, but becomes really difficult with materials like lead, copper or metal alloys, which necessitate a calculation of the required quantity of raw material and involve a risk of losing metal during the casting process. The process becomes harder still when the weights take complex forms, like the octahedral weights from the western part of the Iberian Peninsula, dated to the Late Bronze Age (Vilaça 2003: 262–5; 2011: 141–2, 152–4).

To summarise, the manufacture of weights requires many conditions to be met: an authority guaranteeing the norm, the mastering of abstract mathematical concepts by the users of the weighing tools and the mastering of sophisticated techniques for shaping the weights. We can also argue that this array of competencies has to be organised by the relevant authority in order to impose the norm and maintain the coherence of the system.

Uses and exchange process

One of the most important points concerning the practice of weighing during the Metal Ages, at least regarding western Europe, is to determine the

framework of its use. As we saw, in essence the archaeological evidence refers to precision weighing. Thus, when it comes to the use of this practice in trade, it is only reliable for weighing small quantities, possibly precious materials, but the weighing instruments found are not well suited for trade in bulk commodities. It is important to stress that the lack of evidence for heavy weighing does not mean such a practice did not exist. This lack might be attributable to deficient research and a poor identification of the respective weighing instruments, but precision weighing definitely exists, and we have to ask in which context it would have been used.

There are many possible contexts in which precision weighing might be practised: trade in small quantities, currency exchange, metallurgy, pharmaceuticals or cooking, to name but a few. The difficulty lies in identifying evidence that permits us to define or distinguish uses. This information could, in theory, be provided by the archaeological context, but in fact, evidence showing a link between weighing instruments and the context of their use is still rare. In funerary contexts, where weights and scales are buried as grave goods, they can be associated with other tools, but they do not refer to one particular activity. We find associations with metallurgical equipment, potential evidence for trade or even textile production, which leads us to think that weighing represents an independent activity, not limited to the control of a single category of products (Poigt 2015a: 137).

Concerning money, as stated above, the earliest weights manufactured in the Iberian Peninsula date from the Late Bronze Age, many centuries before the appearance of the first local coinage. Furthermore, the main areas of weight finds do not match the distribution of the Punic and Greek colonies where the first coined money was issued. Thus, we cannot link weighing practice to the control of coined money, whether it be for the weights from grave 200 at El Cigarralejo or for the rest of the Iberian Peninsula.

Where is the place of exchanges in this context? The circulation of goods between the Iberian Peninsula and its neighbours is well attested. However, the relevant networks probably also provided conduits for the movement of ideas, knowledge and people. These contacts are ancient, with long-distance trade since the Bronze Age demonstrated for instance by the Iberian origin of copper used in Scandinavia (Ling *et al.* 2014: 125).

Even if they do not use the same system of measurement or even numeral system, the archaeological evidence shows the capacity of the Iberian peoples to maintain relationships, commercial or not, with near and distant neighbours. At the same time, they were able to handle complex and abstract mathematical

concepts and apply them to their weighing practice. On the other hand, there is no evidence for the use of such weights in trade.

Premonetary currency systems

One of the biggest differences between pre-money and struck money, directly linked to our subject, is the former holding only its own intrinsic value. Thus, pre-money does not require a nominal value as guaranteed by a political authority stamped on it and, logically, a formal transformation does not change the intrinsic value. The main consequence of this principle is the need for a way to evaluate the raw material composing it. Two steps are then necessary, the estimation of the quality of the material and the calculation of its quantity. It is this second aspect which interests us particularly. Indeed, the measuring of quantity by weight is often mentioned (Callegarin and García-Bellido 2012: 123; García-Bellido 2011: 133), even if the archaeological evidence is not obvious.

The presence of pre-money based on a metal standard (principally gold and silver) is well attested for the Iberian Peninsula, with — in some cases — the identification of metrological standards (Callegarin and García-Bellido 2012: 126; García-Bellido 2011: 131). These observations are essentially based on the evidence from hoards, either containing complete objects, destined to be broken up or not, or scrap metal of *hacksilber* or *hackgold* type. One observation that might support an interpretation of these as a form of pre-money is the progressive substitution of these artefacts by coined money in the hoards, with a phase of coexistence of the two categories. However, a link between the units into which the metal is broken up and the weight system is not so obvious. Indeed, the area of the greatest concentration of weight finds (around Murcia, Valencia and Alicante) has not produced many hoards and an exhaustive metrological study is still lacking.

Furthermore, under circumstances where the relevant metrological standards and the precision of weighing are unknown, this type of work faces an inevitable obstacle: if we are looking for some logical sequence in a data set, we always find one. It does not mean that such hoards reflect a weight standard. However, in most cases, the distinction between units of metal weighed to an approximate standard and pieces of metal cut more or less to the same size faces considerable difficulties.

Concerning the potential use of other types of material as premonetary currency, we have little information to go by. Manufactured goods may represent abstract value in commercial transactions. We know for example that textiles could be used as a form of payment during Antiquity, as described in Linear B tablets

for Mycenaean Greece (Luján 2011: 28–9) and we can suspect that precious materials might have played the same role, such as salt, amber or precious stones. However, salt and textiles do not normally survive in the archaeological record and there is no evidence for the use of other materials, at least as far as the Iberian Peninsula is concerned.

Material context

Iberian Peninsula

In order to clearly understand in which context weighing practice evolved and the impact of external influences on it, it is important to provide a quick historical overview of the Iberian Peninsula from the sixth century to the first century BC.

The Iberian area in the east of the peninsula represents a geographical zone where people shared the same language and material culture between the sixth and the first centuries BC (from the end of the fifth century BC where language is concerned) (Figure 1). Writing, in a Phoenician-derived alphabet, has survived in the form of epigraphic inscriptions on pottery, coins or other materials, such as lead sheets (Gorgues 2014: 157). This area maintained relationships with several Mediterranean peoples: first the Phoenicians, then the Greeks and finally the Romans, until the Punic Wars brought about the creation of the two Roman provinces of Hispania in the second century BC, marking the beginning of the progressive Romanisation of the entire peninsula. Since the early sixth century BC and increasingly during the fifth century BC, trade in Greek pottery developed along the Mediterranean seaboard, particularly around Albacete, Alicante and Murcia (Pare 1997: 264), our main area of interest. C. Pare explains this quick development by the previous involvement of the local population in trade with the Phoenicians (Pare 1997: 263).

Thus, the Iberians had been used to interacting and dealing with foreign people for many decades when our set of weights was buried in grave 200 at El Cigarralejo. However, this exposure to foreign trade probably did not transform the local economy for several centuries. Furthermore, M. P. García-Bellido emphasises the tendency of metrological systems to withstand innovations and preserve archaic features (García-Bellido 1999: 363), which makes us think that the Iberian metrological system might have continued unaltered for a long time after the introduction of Mediterranean weighing standards.

The first local coinage, the Iberian *drachma*, appears in the context of the second Punic War, but it is only used in the area under Greek colonial influence

(Gorgues 2010: 69). Before that, we observe the circulation of silver coins issued by Greek colonies like Emporion, which coined *oboles* and *hemioboles* from the fifth century BC onwards, and Rhode, coining *drachmas* since the end of the fourth century BC (García-Bellido and Blázquez 2001b: 129–35, 318–9; Gorgues 2010: 69). The metrology is based on a *drachma* weighing 4.7g, which results from a mix between Phocaic and Punic metrologies. The Punic coins, made of silver or bronze, are introduced somewhat later in the Iberian Peninsula, around the late fourth or early third centuries BC, from the colony of Ebusus (García-Bellido and Blázquez 2001a: 114–15).

A. Gorgues has also commented on the relationship between metrology and coinage and reminds us of the impossibility for a metal or any other material to have a conventional value without agreeing on a system to measure its quantity, either by volume or by weight (Gorgues 2010: 72). However, contrary to him, we think the presence of weighing scales does not necessarily imply the use of a metrological system. We can postulate that the balance permits ‘relative weighing’, this is to say comparing the mass of two products without using weights for measuring. But as stated by Gorgues, the way from weight measurement to the establishment of an agreed weighing system applied to commercial transactions is long (Gorgues 2010: 73).

If the Iberians were probably trading with several foreign peoples, the Greeks are the only ones maintaining permanent settlements in the Iberian area: Emporion, Agde, Rhode (Gorgues 2010: 76). There are various and numerous indicators of the importance of Greek influence on Iberian culture, most notably writing (on lead tablets), imported goods and iconographic influence.

The various interactions of Iberians with other peoples, each with its own distinct metrological system (if not several), make the study of weights and measures much more complex. Obviously, any attempt to deduce metrological standards from the archaeological record needs to compare the available finds to all systems potentially used in the area, with all their fractions and multiples.

History of research

To better understand the matter of Iberian metrology and the current hypothesis concerning it, it is necessary to consider the history of research. Indeed, the latter very much conditioned the current view of the metrological systems in use in the Iberian Peninsula.

For our study area and period of interest, the first scholar to identify weights was I. Ballester at the beginning of the 1930s, taking an interest in the copper

alloy or lead artefacts with a discoid or troncoconical shape and central perforation. These pieces are generally found in Iberian settlements from the provinces of Valencia, Murcia and Alicante, and Ballester was the first to observe the repetition of masses on a regular weighing scale, which led him to identify them as weights. He proposed their matching to a metrological system based on a unit of 4g (Ballester 1930). His study was based particularly on the set of weights from Covalta (construcción 27, departamento b), which were reanalysed by P. Beltrán in 1948, adding specimens from La Bastida de les Alcuses (Moixent, Valencia), Cabeço de Mariola (Alfafara-Bocairent, Alicante), La Serreta (Alcoi-Concentaina-Penáguila, Alicante) and one weight from El Xarpolar (Vall d'Alcalà, Alicante). Beltrán was the first researcher to attribute a foreign origin to the Iberian weights. According to him, the Iberian metrological system uses the same divisions as the Mediterranean systems, an idea which would become a sort of dogma during the following decades. He also identified a 'covaltine' *mina* (501.43g), corresponding to 60 *shekels* of 8.48g, close to the light Babylonian *mina* (504–5g) (Beltrán Villagrana 1948: 136–7).

In 1964, E. Cuadrado published the 13 weights from grave 17 at Cabecico del Tesoro (Verdolay, Murcia) and also the set of ten weights from grave 200 at El Cigarralejo (the latter forming the subject of the present case study), adding them to the previous corpus. He kept the idea of an importation of the metrological system into the Iberian Peninsula, but attributed its origin to the Greeks, because of their influence. So the Iberian metrological system proposed by Cuadrado is composed of a Greek *mina*, divisible into 100 *drachmas*. The best candidate for him was the Solonian *mina*, equal to 436.6g, corresponding with a *drachma* of 4.36g (Cuadrado 1964: 344).

Working with the same corpus, D. Fletcher Valls and C. Mata Parreño organised their analysis according to a chronological framework and left out any artefacts with a doubtful origin. Nevertheless, they kept the standard and the system proposed by Cuadrado (Fletcher Valls and Mata Parreño 1981). Fletcher Valls wrote another paper on the subject in 1995 with L. Silgo Gauche, incorporating a study of the marks observed on some weights. Although they have a diffusionist understanding of the weighing metrology, they applied a mathematical approach, ordering the mass of the weights into groups of 13 values, labelled *a* to *m* (Fletcher Valls and Silgo Gauche 1995: 273).

In 2003/2004, I. Grau Mira and J. Moratalla Jávega based a new article on the weights from the geographical area around Valencia, Alicante and Murcia, adding weights from 14 new sites to the corpus. Combining a search for eastern Mediterranean influence and the detailed observation of the artefacts, they came to the conclusion that various metrological systems were used in the

Iberian Peninsula (based on standards of 7.2g and 8.6g for the fourth and third centuries BC, and another around 7g for the second and first centuries BC), some existing at the same time (Grau Mira and Moratalla Jávega 2003/2004: 50). In particular, they saw evidence for the existence of adjustable weights, which functioned by filling the central perforation with an insert of a different metal (iron or lead in most cases) or the attachment of a ring or a wire. They explained this adjustment as a way to make the weights usable simultaneously within two different metrological systems (Grau Mira and Moratalla Jávega 2003/2004: 43–4).

Adopting another method, we recently proposed a different system than those presented above. Starting with the set of ten weights found in grave 200 at El Cigarralejo, we tried to reconstruct the system used to build it, based only on the arithmetic links between weights (Poigt 2015a).

The set from grave 200

The set of ten weights from grave 200 at El Cigarralejo, published originally by Cuadrado (1964), is particularly interesting with regard to Iberian metrology. Its context of discovery, a tomb, and its arithmetical construction permit to formulate many hypotheses concerning it. Furthermore, its comparison with weighing instruments from neighbouring sites gives an idea of the standards shared among the Iberians.

The tomb in question is a cremation grave, maybe of two individuals, containing the weighing instruments alongside weapons, harness elements, spindles, ornaments, pottery and other artefacts. With more than 200 grave goods, it is the ‘richest’ tomb of the 494 graves excavated in the necropolis.

Photogrammetry

Three-dimensional photogrammetry was used to accurately record the objects under study. This technique gives 3D properties to an object derived from 2D images, using specific algorithms. In most cases, particularly for aerial photogrammetry, the models obtained are not full 3D objects but only convex surfaces (Bourke 2012: 71). Our objective here is to create complete meshes, i.e. closed models that permit full rotation as well as the calculation of their volume. Combining mass, volume and 3D reconstruction, we should be able to reconstruct the original mass of deteriorated or adjusted weights, opening up opportunities for new metrological perspectives on the evolution, rejection or adoption of weighing systems.

For this study, we used the *Agisoft Photoscan*[®] software, permitting fast and precise treatment of the images. The usual method consists in taking pictures by moving the camera around the object. In our case, to save time and enhance precision, the camera was fixed and the artefact was rotated using a turntable. A problem that may arise with this method when stitching together the different images is caused by the object's movement in relation to the lighting source, which remains stationary. In order to reduce the impact of the stationary lighting source, it is possible to place the turntable in a small lighting tent, which diffuses the light and reduces uneven shadows.

Concerning the scan itself, pictures were taken at four different angles, corresponding approximately to 40°, 70°, 110° and 140° from a vertical camera position. In practice, the object was turned over between taking images at the two first angles and taking pictures at the latter two. At each angle, between 24 and 36 images were taken, depending on the artefact (smooth or rough surface, circular or irregular shape etc.) (Figure 2).

After this step, the rest of the process does not require access to any archaeological material, which is an important advantage of the method. The time required for recording an object *in situ* rarely exceeds ten minutes. However, masking is an essential requirement for the further procedure. It consists simply in applying a rectangular mask around the artefact on every picture in order to isolate it from any background features. Using the software, the 3D model is then built in four steps: alignment of the images, construction of the point cloud, construction of the mesh, and construction of the texture. It should be noted that this last step is not essential for determining the volume and only affects visual appearance. In most cases, the entire process could be done without modification of the data, but in some cases, particularly with the perforated artefacts, cleaning of the point cloud is essential, that is to say, deleting any intrusive points (due e.g. to shadows in the area of the perforation). The final step consists in applying a scale to the digital model through the use of suitable reference points. For this, we used points from a measuring scale visible in the pictures.

Photogrammetry is not normally used with the objective of calculating volumes of objects, and it was necessary to test its reliability for this purpose. Thus, we used it on a wooden sphere, because its volume can be calculated by applying the rules of geometry, and we obtained a deviation below 1% between the geometrical calculation and the numerical calculation derived from the 3D model. For the weights from El Cigarralejo we tried a range of different methods and we observed that several factors could alter the calculated volume. These are the uniformity of lighting between images, the shape of the object, the distance between the object and the scale, or the method of mesh creation. The

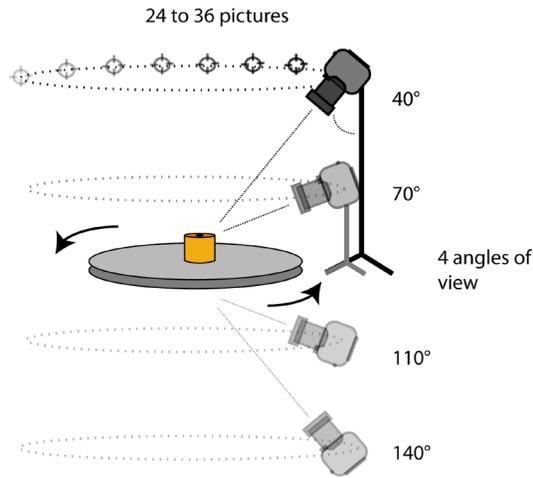


Figure 2. Photogrammetry method: schematic representation.

light has to envelop the shape of the object without overexposing and requires a routine control of the pictures. The perforations, when they are relatively deep, can be the cause of a faulty mesh, because the inside of the perforation does not appear in the pictures. As far as the scale is concerned, it has to be placed as closely as possible to the artefact. However, from our experience, the main distortion for the calculated volume comes from the use of two separate point clouds for constructing the mesh, corresponding to the two faces of the object, and aligning them subsequently. Every time we used this method, we observed deviations in the calculated volume of around 5% compared to models built directly. Changes in the number of images taken, focal length or viewing angles respectively cause variations below 1.5% in most cases.

In our point of view this method holds real potential for metrological studies. Determining the exact degree of precision for this method will necessitate other tests, but based on work carried out so far we can consider it to be around 1–2%. We think these figures are compatible with an intended use in ancient metrology studies, but it is necessary to take them into consideration.

Reexamination

E. Cuadrado conducted his study of this set of weights fifty years ago and it appears necessary for us to take a fresh look at this material.⁴ In spite of a few small deviations, the masses recorded today are not very different from

⁴ All the archaeological finds from the site are currently kept at the Museo de Arte Ibérico ‘El Cigarralejo’ (Mula, Murcia, Spain).



Figure 3. 3D models of the weights from grave 200.

the ones measured by Cuadrado in 1964. This fact is reassuring for metrology studies; it allows us to postulate that the masses did not change significantly since the excavation in 1963. New data are available from the weighing of the two artefacts from tomb 18. These copper alloy weights, labelled here Cig-K and Cig-L, weigh 5.56g and 90.74g respectively.

An examination with the naked eye already provides some information about the weights. Firstly, the functioning of the weights as a set is evident. Their dimensions allow them to be neatly stacked (Figure 3). Secondly, the wear observable around the perforation on the lower face supports the hypothesis formulated by Beltrán (1948: 134), and subsequently repeated several times in the literature, that they would have been stored threaded on an axis. A small indentation on the inner surface of the perforation of some weights leads us to think that this system could at some stage have been substituted by keeping them threaded on a simple string (Figure 4).

Cuadrado exposed the morphological heterogeneity of the pieces even though the drawings accompanying his article did not clearly support his observation. This dissimilarity between pieces was corroborated by the present study, as

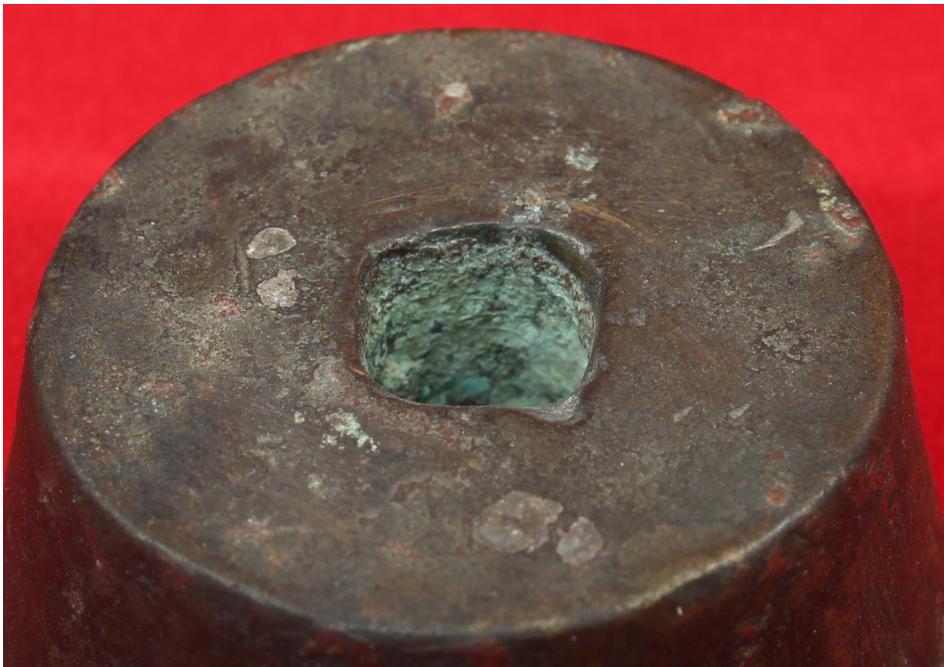


Figure 4. Detail of wear on one of the weights.

demonstrated by the digital models. All the weights belong to the category of cylindrical weights according to the typology proposed in Poigt (2015b: 178), but if weights E, G, H, I and J are clearly of a truncated conical shape with a slightly concave outer surface, the others (A, B, C, D and F) look more discoidal, if not cylindrical in the case of weight B (Figure 5).

In a previous article, we proposed the identification of an indigenous system on which the set from grave 200 at El Cigarralejo is based (Poigt 2015a). The method employs a very basic calculation: a 'division table' (Table 1). Every intersection in the table represents the result of the division of the row by the column. In this way, for every column's entry, we have its ratio compared to the other data. In our case, we note a particularly interesting feature of weight Cig-F, of 20.48g. It has interesting relations with the other weights. Indeed, it presents whole numbers for the multiples and logical associations for the fractions, which permits to consider it as the base unit or standard. Without going into too much detail regarding the other results, we see that in relation to weight Cig-F, weights G, H, I and J represent multiples ($\times 2$, $\times 4$, $\times 6$ and $\times 10$) with only small deviations. Considering the fractions, we can reconstruct them as $1/10$, $1/6$, $1/4$, $1/3$ and $3/4$, which is consistent with the idea of a system mixing decimal and duodecimal counts.

The way the set has been constructed further supports this hypothesis. Considering Cig-F as the base unit, the set of ten weights starts with a $1/10$ fraction and ends with a multiple of 10. Finally, combining the weights, it is possible to constitute a fraction of $1/2$ and an uninterrupted sequence of multiples from 2 to 24 times the base unit. Adopting a theoretical reconstruction with a standard equal to 20.77g, the average deviation equals approximately 1% (Poigt 2015a: 144).

Weights		Cig-A	Cig-B	Cig-C	Cig-D	Cig-E	Cig-F	Cig-G	Cig-H	Cig-I	Cig-J
	Mass (g)	1.98	3.38	5.01	7.4	15.83	20.48	41.46	81.65	125	208.45
Cig-A	1.98	1	0.59	0.4	0.27	0.13	0.1	0.05	0.02	0.02	0.01
Cig-B	3.38	1.71	1	0.67	0.46	0.21	0.17	0.08	0.04	0.03	0.02
Cig-C	5.01	2.53	1.48	1	0.68	0.32	0.24	0.12	0.06	0.04	0.02
Cig-D	7.4	3.74	2.19	1.48	1	0.47	0.36	0.18	0.09	0.06	0.04
Cig-E	15.83	7.99	4.68	3.16	2.14	1	0.77	0.38	0.19	0.13	0.08
Cig-F	20.48	10.34	6.06	4.09	2.77	1.29	1	0.49	0.25	0.16	0.1
Cig-G	41.46	20.94	12.27	8.28	5.6	2.62	2.02	1	0.51	0.33	0.2
Cig-H	81.65	41.24	24.16	16.3	11.03	5.16	3.99	1.97	1	0.65	0.39
Cig-I	125	63.13	36.98	24.95	16.89	7.9	6.1	3.01	1.53	1	0.6
Cig-J	208.45	105.28	61.67	41.61	28.17	13.17	10.18	5.03	2.55	1.67	1

Table 1. Division table used to spot correspondences between weights.

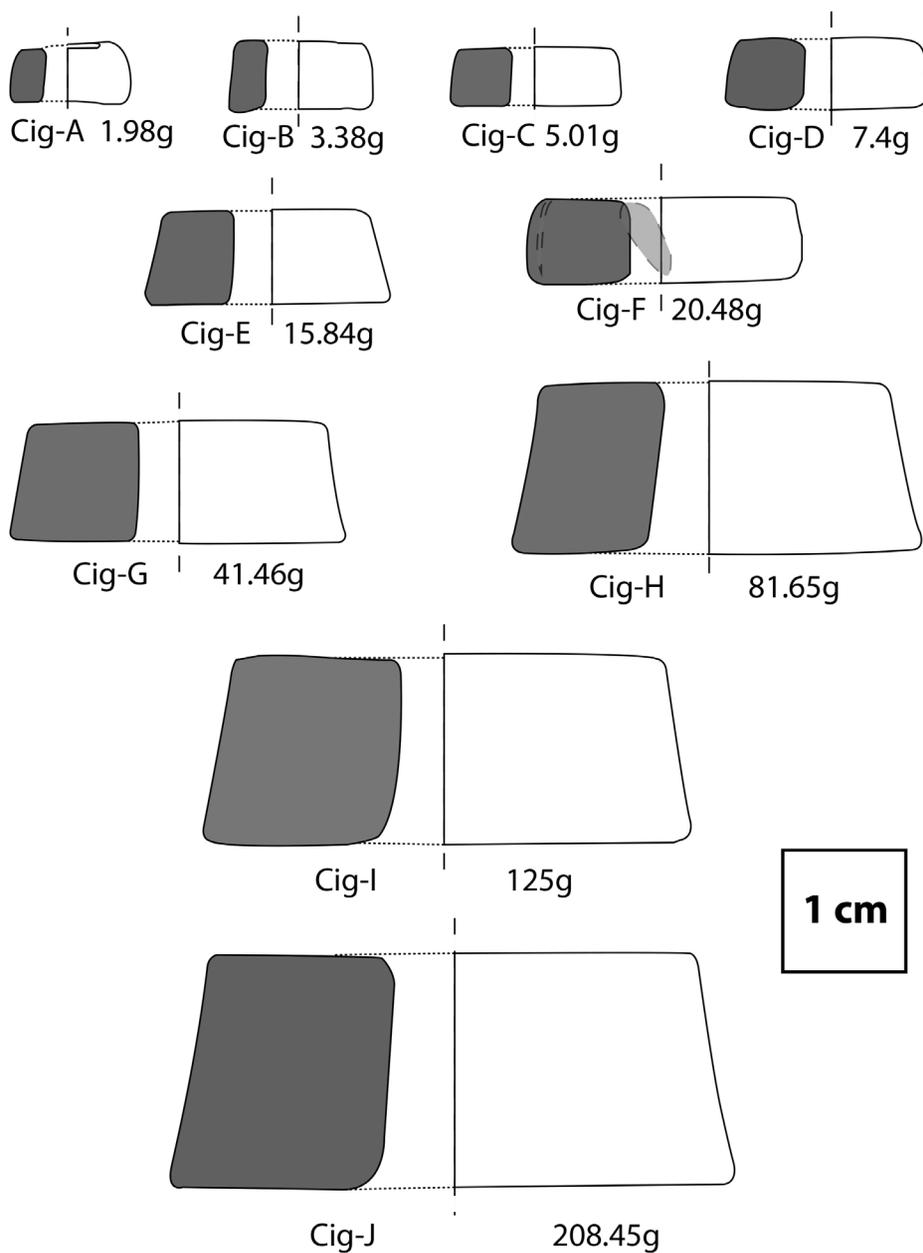


Figure 5. Weight units from grave 200.

The examination of the set does not invalidate the above proposition, but it is interesting to make a few observations. We can further reflect on the morphology between weights. On the one hand, the metrological coherence of the set is obvious; on the other hand, this is not incompatible with the idea of a rebuilt assemblage. There is no evidence permitting conclusions about the possible reconstruction of the set, except for the morphological aspect of the pieces. The reconstruction of weight F in its state prior to the cutting of the two notches, according to our digital modelling, gives it an approximate mass of 21.0–21.5g. This difference of mass is too small to allow for metrological conclusions. Even if it is harder to achieve, the complex metrological make-up of the set could have been devised when the set was rebuilt (assuming that we are indeed dealing with a rebuilt set). If that is the case, the craftsperson probably made slight modifications to adjust the mass of individual weights (through notching, planing sides and so on).

One of the principal pieces of information from this new examination concerns weights K and L from grave 18. The two tombs are not contemporaneous but separated by approximately one generation, judging by the associated grave goods. The possibility of a succession in time of two different systems cannot be totally ruled out. If the weights from grave 18 do not function very well with a standard of 20.77g, within a logical sequence similar to those from grave 200, conversion between the two systems is quite easy. Indeed, Cig-K (5.56g) approximately equals Cig-C, that is to say a 1/4 fraction, and Cig-L (90.74g) corresponds to 4.5 times the base unit from grave 200 (Cig-F).

We cannot go further in the interpretation of the weights from grave 18, except for saying that they represent a different metrological construction from the ones in grave 200. This observation supports the idea of local systems, functioning within a very small sphere of influence or during a short time. The possible existence at the same site of two weighing systems, almost contemporaneous, urges caution when it comes to large-scale metrological studies based on a statistical approach incorporating all the data from the Iberian area, independent of chronology and geography. Obviously, the data from this necropolis are too sparse to determine if we are dealing with a single system expressed in different sets of multiples, or if there are two different systems functioning simultaneously. For this reason, it is necessary to expand our observations and look at the compatibility of the system from grave 200 with evidence from neighbouring sites.

Comparisons

The Iberian Peninsula is one of the areas in Europe that have provided most balance weights, with almost 300 artefacts identified. Approximately two thirds of this corpus are concentrated in the small region around Alicante, Murcia and Albacete. This area corresponds roughly to the Roman *Contestania*, a name used for the region inhabited by an indigenous population referred to as *Contestani*, to whom some scholars, particularly I. Grau Mira and J. Moratalla Jávega (2003/2004), attribute a specific material culture. We are choosing in this article to avoid the term *Contestania*, only known from later Roman sources, in order not to introduce any chronological confusion. Nevertheless, the fact is that we find a great quantity of balance weights in this geographical zone, both in funerary and settlement contexts (Figure 1).

As outlined above, several previous works have treated these artefacts, including those from El Cigarralejo. It is not the aim of the present contribution to provide an exhaustive list of weights from the Iberian Peninsula, thus we will only compare our results with metrological data furnished by previous studies.

The first observation we can make concerning Iberian weights is that we cannot easily identify the standard from El Cigarralejo within that corpus. The reason behind this is not the absence of objects weighing approximately 20.77g but, on the contrary, a large number of weights whose masses fall close to this figure, without forming a coherent range. Indeed, nine weights fall within c. 5% of the standard from El Cigarralejo (19.73–21.81g), but we do not observe a clear concentration of masses around it (Figure 6). Significantly, the same observation can be made for the double standard of 41.53g. The difficulty comes from the impossibility to differentiate clearly between a weight approaching a theoretical value with a lack of precision and a weight corresponding to another metrological system, but with a multiple that lies close to that first theoretical value (for example, the double of the standard from El Cigarralejo could be confounded with ten *drachmas* of 4.36g).

Finally, it is maybe the multiple ten which permits the easier comparison, because the imprecision of the measures is smaller than the difference between two distinct weights. There are 15 weights with a mass between 191.04g and 211.58g, and ten of these show a deviation of less than 2% from the tenfold multiple of the standard from El Cigarralejo. These pieces originate from La Serreta, La Bastida de les Alcuses (sections 16, 100 and an isolated find), Covalta (structure 27 and isolated finds), Cabecico del Tesoro and El Puig. We can postulate that the weights approaching 195g correspond to other systems.

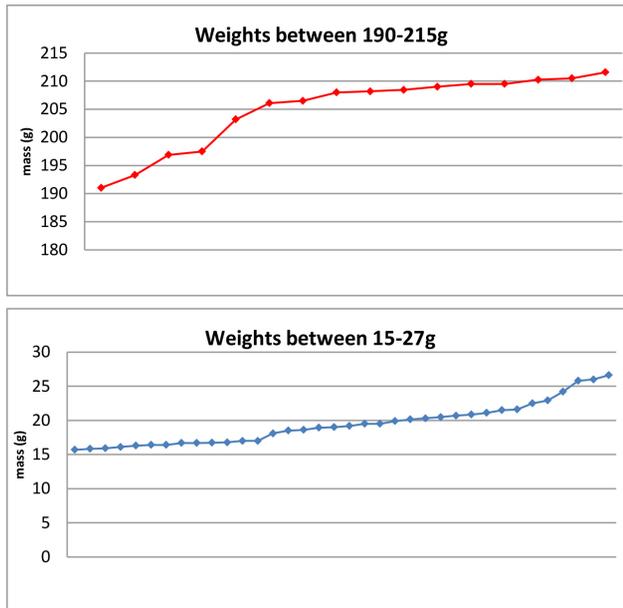


Figure 6. Mass of Iberian weights around the standard of 20.77g and its multiple by ten.

Indeed, an imprecision of 10g seems unlikely given the precision of the set from grave 200.

I. Grau Mira and J. Moratalla Jávega already proposed an identification of several metrological systems, and the one based on the weights from El Cigarralejo could just be another one. But are other sets metrologically similar to it? We can postulate that sets share the metrological system of El Cigarralejo if they use similar multiples and fractions or another logical sequence starting from 20.77g. In a previous study on the subject, we attributed a percentual value to the extent to which other sets matched the metrological system from El Cigarralejo, based on the match of their respective component weights with those known from El Cigarralejo (Poigt 2015a: 145–6). It is probably necessary to break down this average value and distinguish between individual fractions and multiples to shed light on the problematic points. Doing so shows the weak correspondence that generally exists between the system from El Cigarralejo and those from neighbouring sites (Table 2). Nevertheless, excluding isolated weights, we can identify two sets as having important similarities with the one from grave 200. The first is a set of four weights from structure 27 at Covalta (42.2g : 81.8g : 122.25g : 209.5g). The second is the set from section 100 at La Bastida de les Alcuses, also composed of four weights (19.9g : 82.3g : 123.8g : 208g). In these two cases, the absolute average percentage of deviation amounts

	1/10	1/6	¼	1/3	1/2	3/4	1	2	3	4	5	6	7	8	9	10	24
Cabeceo del Tesoro	2.08	3.46	5.19	6.92	10.38	15.57	20.77	41.53	62.30	83.06	103.83	124.59	145.36	166.12	186.89	207.65	498.36
	-1.8%	15.6%	1.4%	24.8%			-4.5%	-8.9%		-0.2%		-0.5%				-2.0%	
Cabezo Lucero					6.0%												
Cap Negret						-5.4%											
Covalta								1.6%		-1.5%		-1.9%				0.9%	
Covalta HC	-8.5%	6.9%		18.5%		2.7%	-1.3%	-4.8%		-5.4%		2.7%				1.4%	
El Cabeçó de Mariola				13.8%	23.3%	7.7%	-4.3%	-15.3%						-4.5%			
El Cigarralejo 18			7.1%							9.2%							
El Molar 134								7.9%									
El Molar 135								6.1%									
El Monastil			-7.5%	2.3%		-7.5%											
El Oral						-4.4%											
El Puig		-11.0%				7.4%		-1.3%								1.9%	
El Xarpolar								-14.6%			3.1%						
La Albufereta			-11.3%			3.4%						-5.6%		3.9%			
La Alcudia						-3.0%	24.7%	-24.2%			7.4%						
La Alcudia HC						-4.1%		0.0%	-10.7%	1.0%		-0.2%				0.7%	
La Bastida de les Alcuses 16					-16.2%	7.2%	4.0%	-1.0%									
La Bastida de les Alcuses 100							-4.2%			-0.9%						0.2%	
La Bastida de les Alcuses 118	18.0%	-4.6%	-13.3%	21.4%		7.2%											
La Bastida de les Alcuses HC	20.4%	-4.0%	-3.7%	2.9%	-9.9%	16.2%	10.0%	-9.0%	9.8%	-4.6%	-1.6%	2.8%			3.4%	-0.6%	-1.0%
La Escuera							0.4%										
La Serreta		-4.6%		13.1%		0.4%	-6.1%	-1.9%				-3.2%	3.1%			-0.3%	
Nicropole de Villaricos									-14.9%								
Orteyl				11.2%			10.4%	5.2%		11.5%		6.7%					
Puntal de Salinas				15.6%	-16.2%					-8.5%							
Tossal de Cala						-11.9%			13.7%								

Table 2. Comparison between Iberian weights and the weighing system used for the set from grave 200.

to 1.5%, an entirely acceptable figure.⁵ We also found nearly the same values in large series of weights without any precise context from Covalta, La Bastida de les Alcuses and La Serreta. In some sets, such as those from Cabecico del Tesoro or La Bastida de les Alcuses, section 16, we see values that align well with the standard from El Cigarralejo, while others cannot be matched.

Conclusions

As we have seen, the use of weighing during the Iberian period is multifaceted. It takes place within a very complex system of thinking, where the metrological and mathematical aspects are incorporated into a social, political and possibly religious environment. For this reason, we should be cautious to approach it from a modern perspective regarding metrology as a trade tool, controlled by institutions and not subjected to personal interpretation.

Consequently, the weighing of goods in order to assign them a premonetary function is possible, but difficult to prove. In effect, the multiplicity of relationships (economic, social, political and so on), as well as the different trade networks and metrological standards, obscure our image of the practice and of its framework of use. This is exacerbated by the identification of exogenous standards as indigenous and the difficulty to establish their order in time and in several cases their geographical origin. For this reason, the research concerning weighing standards in hoarded goods faces the issue of determining which one is credible in regard to its cultural, geographical and chronological context. For the area around Valencia, Murcia and Alicante, where most of the Iberian weights come from, we cannot establish a clear link between the practice of weighing with the identified standards and the premonetary process. However, such a link may be easier to identify for other regions of the Iberian Peninsula, as is demonstrated for the hoard from Driebes, based on the Syrian *shekel* (García-Bellido 2011: 131), or the jewellery from Seville and Padilla, with a potential connection to the weighing system from Cancho Roano (García-Bellido 1999: 377).

In order to answer the remaining questions, a better understanding of the emergence and of the development of weighing instruments in the entire Iberian Peninsula is required. Presently, research demonstrates the existence of various metrological systems, expressed in weights with morphological similarities across the entire territory. At the moment, however, we cannot satisfactorily explain this phenomenon. Answers will likely be coming from the

⁵ The deviations are respectively equal: 1.6%, -1.5%, -1.9% and 0.9% for Covalta, and -4.2%, -0.9%, -0.6% and 0.2% for La Bastida de les Alcuses.

identification of new weights which will fill the existing gaps in time and space. Understanding the origin of the morphology of the Iberian weights and of the indigenous standards will probably open up new lines of research on weighing practices and their implementation.

To conclude, sets of weights with complex arithmetical construction, like the one from grave 200, show that the Iberians mastered abstract concepts and knew how to apply them to the physical world. On the one hand, we observe hoards with a premonetary purpose; on the other hand, we cannot associate their creation directly with the process of weighing. The link with trade is also not clear; because of the limited mass of weights and the limited size of scales, the tools identified are ill-suited to weigh great quantities of material. It is difficult to draw conclusions about the link between trade, premonetary currency and weighing for the Iberian Peninsula. To make progress in this matter, a considerable amount of work is still necessary when it comes to identifying relevant artefacts and interpreting them.

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