LEONIE HOFF

FINGERPRINTS ON FIGURINES FROM THONIS-HERACLEION

Summary. *This paper studies ancient fingerprints to produce an estimate of the age and sex of the makers of several terracotta figurines found at Thonis-Heracleion in Egypt, dated to the Late and Ptolemaic periods (seventh–-second centuries BC). This is only the second study of its kind to discuss the use of ancient fingerprint impressions from Ancient Egypt and the first to apply this method to Late Period/Ptolemaic material using RTI (reflectance transformation imaging) to obtain measurements. Albeit at a preliminary stage, the findings suggest the involvement of men, women, and children in figurine production, both for locally produced wares and imported Greek figurines, contrary to the image of figurine-makers presented in ancient Greek literary sources, which portray figurine production as a predominantly male profession. The results also allow insight into questions of training and apprenticeship of ancient figurine production, with various stages of training being represented in the data.*

INTRODUCTION

The use of fingerprint evidence in forensic and criminal investigation has been long exploited and is well established. Fingerprint evidence is also applicable in archaeology where its utility is less well-known (Kantner *et al*. 2019, 12221). In recent years, a handful of papers have been published outlining methods for using ancient fingerprint evidence (*paleodermatoglyphics*), particularly from ceramics, to determine the age and sex of the potter who left their impressions in the clay (Bennison-Chapman and Hager 2018; Faux-Campbell 2018; Fowler *et al*. 2019; 2020; 2022; Forte and Miniaci 2023). Male and female hands are sexually dimorphic with regards to the density of epidermal ridges and the breadth of those ridges (Ashbaugh 1999; Kamp *et al*. 1999; Králík and Novotný 2003; Sanders 2015). This study uses fingerprint evidence from terracotta figurines found at Thonis-Heracleion in Egypt dating to the Late and Ptolemaic periods to determine the age and sex of the individuals who left their imprints on the objects. The individuals so represented were likely involved in the creation of the figurines since the clay was still wet when the imprints were made. In the case of Thonis-Heracleion, the idea of using fingerprint evidence was particularly appealing as it offered a way to get a sense of the people who lived and worked in this once grand *emporion*. Monumental artefacts such as sculpture and royal inscriptions have been well preserved at this site, demonstrating the city's role as a major harbour in the Late Period and its connection to the Ptolemaic dynasty (Goddio and Clauss 2006; Goddio 2007; Thiers 2009).

It is, however, much harder to grasp the lives of ordinary people there, as their mudbrick non-monumental architecture has either not survived or has not yet been located and excavated. Likewise, the funerary evidence at the site has been very limited so far, thereby excluding access to a major source of information on the lives of the city's inhabitants. Consequently, studying the fingerprints from these figurines gives a more direct insight into life at Thonis-Heracleion, into the kinds of objects that were used in daily life, trade with the Greeks, and the existence of local artisans. In addition, this method may illuminate questions about the *chaîne opératoire* of figurine production, such as the division of labour and the training of apprentice figurine-makers. Out of a collection of over 60 terracotta figurines from Thonis-Heracleion, nine were identified with clearly visible fingerprints (Fig. 1). With the sample size being currently rather limited it is hoped that this preliminary study can be expanded in future.

Following Fowler's paper on using fingerprint evidence to track the division of labour in Early Bronze Age Israel (Fowler *et al*. 2020), this paper combines fingerprint ridge density and fingerprint ridge breadth evidence to determine the age and sex of the figurine makers. Fingerprint ridge density refers to the number of epidermal ridges found in a set area, usually a 25 mm^2 square. Fingerprint ridge density has been shown to reliably indicate the biological sex of an individual (Acree 1999; Králík and Novotný 2003; Wuetcher 1989). It is, however, less effective in determining an individual's age other than the distinction between adult and subadult. Fingerprint ridge breadth however decreases with age and differs to some degree between the sexes, allowing for a reconstruction of an individual's age and sex, although fingerprint ridge density appears to be more effective in determining an individual's sex. Consequently, the two methods work well

FIGURE 1
Example of a figurine (H20257) from Thonis-Heracleion with close-up of the fingerprints found on the reverse and interior. Photographs author @ Franck Goddio/Hilti Foundation.

in combination. With regards to fingerprint ridge breadth, the maximum visible number of furrow-ridge pairs was measured and then divided by the number of pairs to give an average ridge breadth, following the method outlined by Kamp (Kamp *et al*. 1999, 311). Kamp's formula allows for an estimate of the individual's age based on the fingerprint ridge breadth. Ridge breadth also allows for a distinction between children and adults overall and between men and other individuals; however, it is less reliable in distinguishing between adult men and women (Kamp *et al*. 1999, 314–15). Notably, the only other study that so far exists on Ancient Egyptian material is a study by Forte and Miniaci which discusses terracotta figurines from Middle Kingdom El-Lahun (Forte and Miniaci 2023). In their study Forte and Miniaci use ridge breadth alone to determine the age of the figurine makers (Forte and Miniaci 2023, 9). The present study is thus the first of its kind to use both ridge breadth and ridge density analysis on Egyptian figurines.

OVERVIEW OF THE SITE AND ARCHAEOLOGICAL CONTEXT OF THE ASSEMBLAGE

Thonis-Heracleion was a major port-city in Egypt in the Saite period and into the Ptolemaic period (Robinson and Goddio 2019, 444). Located around 30 km to the north-east of Alexandria, it was situated at the entrance to the Canopic mouth of the Nile, in Abukir Bay (Robinson and Goddio 2015, 16). It is known from the material culture and textual evidence of the site that the city served in the collection of taxes for incoming trade and as a point of defence towards potentially troublesome incomers, regulating access to the Nile Delta (Robinson and Goddio 2019; Von Bomhard 2017, 435–6). The city appears to have been founded in the eighth century BC, when the earliest finds at the site are attested (Sabine Laemmel pers. com.; Grataloup in Robinson and Goddio 2015, 138–9, fig. 7.2.1).

Interactions with Greek traders and migrants left a strong influence on the city, with the city displaying a wide range of Greek material culture. Recent excavations have suggested the existence of a Greek-style sanctuary of Aphrodite at the site (Franck Goddio pers. com.). The city flourished for several centuries as a grand *emporion* in the Mediterranean, before experiencing a decline after the foundation of Alexandria which appropriated Thonis-Heracleion's status as the main harbour of Egypt (Robinson and Goddio 2019, 444–5). The city remained influential in the celebration of the cult of Amun-Gereb, a cult that was instrumental to legitimizing pharaoh's rule in the Ptolemaic period (Robinson and Goddio 2019, 445). However, with Alexandria's foundation the city stopped enjoying the same degree of trade with the Greek world, and Greek imports significantly decline in the Ptolemaic period (Grataloup in Robinson and Goddio 2015).

Thonis-Heracleion's location also exposed the city to a greater risk of experiencing natural disaster. The city rested on unstable sediments that ended up giving way under the weight of the monumental stone architecture placed upon it. Furthermore, being situated only a few meters above sea level, little protection was offered against tidal waves and rising sea levels (Goddio 2007, 8; Robinson and Goddio 2024, forthcoming). A major cataclysm occurred in the mid-second century BC, when much of the city was destroyed, effectively setting a *terminus-ante-quem* for the majority of the material culture at the site (Goddio 2007, 1, 75). Following the loss of what remained of the city beneath the sea in the eighth century AD, Thonis-Heracleion faded from memory until it was rediscovered in the late 1990s. The terracotta figurines discussed in this article have all been located during excavation of the site in the last 20 years and attest to the strong Greek influence on the city, consisting either of Greek imports or local production that adopted Greek techniques.

In terms of contextualizing the figurines within the city, they come from several distinct locations. A cluster of figurines was found in excavation square J8 (Fig. 2), towards the north-east of the city, on an island by the point of entry to the harbour that was used during the earlier phase of occupation of the city. A Greek tumulus burial has been identified on this island with which a range of Greek material from the fifth–fourth centuries BC was associated, such as banqueting ceramics and statuettes (Franck Goddio pers. com.). H20257, H20258, H20259, H20636, which consist of a mixture of Greek imports and local imitations of Greek wares, form part of this grouping.

H11706, H2795 and H18824 come from the south of the Central Island, on which the later temple of Amun-Gereb was situated and seem to form part of a collapse deposit during the cataclysm which occurred in the second century BC. A range of identical ceramic wares and figurines were found as part of this collapse stratum, suggesting the existence of market stalls selling these products near the quayside, which fell into the channel during the earthquake (Robinson and Goddio 2024; forthcoming). Figurines from this deposit tend to be locally produced rather than Greek imports and can be tightly dated to the mid-second century BC when the cataclysm took place.

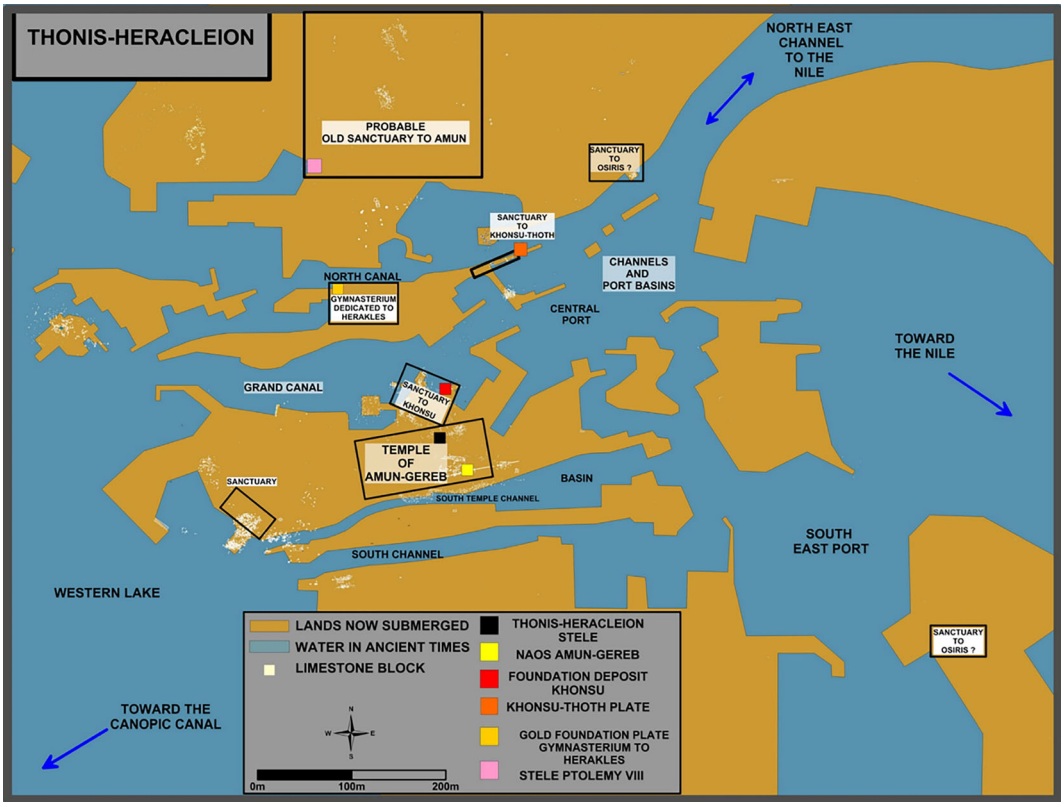

FIGURE 2
Map of the known sanctuaries and major finds at Thonis-Heracleion. Map Franck Goddio © Franck Goddio/IEASM), after Robinson and Goddio 2019, 438.

H4076 was found in H4, in the Grand Canal, which ran north of the Central Island on which the temple of Amun-Gereb was situated. Several bronze statuettes were found in this canal, although not as many terracotta objects. Specifically, H4076 was found in proximity to a large quantity of bronze coins, gold jewellery, bronze cult items, largely dated to the fourth–second centuries BC.

Lastly, H18396 was found during a survey of the mobile sands overlying the stratified deposits from the site and was thus out of context. With the exception of H18396, the remaining statuettes have a secure archaeological context with clear recording of their findspots within the site, a feature that is practically unparalleled among known Graeco-Egyptian terracotta figurines (Török 1995, 22). This knowledge of provenance is relevant for the use of *paleodermatoglyphics* in that it may be possible to identify specific figurine-makers within the assemblage with further research, since the objects coming from the market collapse stratum will be contemporary and originate from a few market stalls, with some of the objects perhaps being produced by the same individuals.

CHARACTER OF THE ASSEMBLAGE AND HYPOTHESIS

Table 1 outlines the assemblage in terms of the likely origin of the figurines which will be relevant when estimating shrinkage rates for the objects. Production origin was estimated based on the typology of the figurines and the clay that was used: traditional Egyptian Nile silt fabrics for example are made from a characteristically bright red or brown clay that tends to be highly micaceous and coarse (Higgins 1967, 132). This clay is so coarse that it is not typically suited to

TABLE 1
Table outlining the figurine assemblage in terms of origin, date, location of imprints and object numbers

Object number	Object description	production origin	Date	location of fingerprint impressions
H2795	rectangular statuette base, in contrapposto stance, likely Greek subject; fine marly clay	Greek import?	Fourth-second centuries BC?	base
H4076	rear of a pig, Nile silt fabric, coarse	local	Fourth-second centuries BC	interior
H11706	child deity, probably Harpokrates; Nile silt clay, less coarse than other fabrics	local	Second century BC	interior
H18396	reclining male figure, possibly Harpokrates; marly fine clay	local?	Third-second centuries BC?	interior + back
H18824	*Protome*, front and back modelled; red clay, probably Nile silt, but finer than other examples	local	Second century BC	interior
H20257	seated *hierodoulos*, fine orange clay, possible Greek/Italian import	Greek/Italian import	Fourth-third centuries BC	interior, backside + base
H20258	theatre masks, fine grey clay, possibly Alexandrian fabric	Alexandria?	Fourth-third centuries BC	interior + exterior
H20259	*protome*, front only, Greek fabric? Fine beige/red clay	Greek import?	Fifth-fourth centuries BC	interior
H20636	Dionysus, similar clay as 20259, fine and beige; imprints on bottom, probably also on interior, but not possible to access without breaking figurine	Greek import?	Fifth-fourth centuries BC	base

thin-walled or highly detailed figurines (Fischer 1994, 20). However, in the Ptolemaic period the coroplasts developed a finer clay that allowed for the production of thin-walled and highly detailed objects such as the well-known Tanagra figurines, comparable to the fine Greek clays (Higgins 1967, 132–3; Dunand 1990, 10). Typology can be a determining factor in estimating the origin of figurines, for example figurines of Harpokrates are more likely to be locally produced, as this subject choice is extremely common in Egypt in the Ptolemaic period (Fjeldhagen 1995, 14). On the other hand, figurines that are purely in a Greek style (such as the Tanagra type) are more ambiguous, as they could have been either imported or produced as local imitations. An interpretation of the origin of such figurines will depend on the type of clay that was used and on details in the manufacturing techniques.

As the table shows, five out of the nine figurines are likely from Egypt, with one of those local objects probably originating from Alexandria. Four figurines are likely Greek imports, with one potentially coming from southern Italy. In terms of manufacturing differences, the Greek imports are almost always hollow and moulded. Likewise, the local fabrics are also moulded and often hollow, being of a later date when Greek culture had made its mark on Egyptian figurine-production through the import of moulding techniques from the Greek world (Dunand 1990; Mollard-Besques 1963, 6–7).

The figurine-maker was known in Ancient Greece as *koroplathos*, a craftsman 'held in low esteem, whose wares were principally used as playthings for children' (Higgins 1967, 1). Indeed, an example of this disdain is when the great sculptor Pheidias is termed a *koroplathos*, in what appears to be an insult (Isocrates, *Epistulae*, 15.2). The etymological origin for this term derives from *πλάσσω*, to form/mould, and *κόρος*, boy (in certain contexts a word also used for doll/puppet) (Montanari 2015). *Koroplathos* has a male ending, suggesting that this profession was typically exercised by men, and the remarks concerning Pheidias would also work better with a male figurine-maker. Notably, ancient Greece in fact had different words for figurine makers (*koroplathos*), lamp-makers (*lychnopoios*), and potters (*kerameous*), suggesting that different types of ceramic objects were not usually produced by the same professional craftsman (Rotroff 2021, 272–3). The following study may serve to challenge or verify this portrayal of the figurine-maker in Greek sources. Terracotta figurine workshops are attested in the Greek world (Doulgeri-Intzesiloglou and Arachoviti 2019), though no fingerprint analysis has been performed on material from such sites.

In contrast, little is known about Egyptian coroplasts. Consequently, we must rely wholly on the products themselves to learn about Egyptian figurine makers. Figurine workshops have been attested in Egypt dating from the Late and Graeco-Roman periods at Naukratis and Memphis (Thomas 2015, 13). So far, however, there is no definitive proof for ceramic workshops at Thonis-Heracleion, although there is some evidence for metal workshops at the site (Heinz 2013, 127) and given the uptake in local ceramics during the Ptolemaic period we might expect coroplastic production to have taken place.

Recent studies of fingerprints from varying time periods and cultures present evidence for the involvement of children in the process of production (Fowler *et al*. 2019, 1497). Fingerprint analysis of the figurines from Thonis-Heracleion might also offer clues as to the role of children within the labour force. Their presence is likely, given the nature of the work, requiring little physical strength and parts of which were relatively low-skill, consequently suiting the inclusion of children in the workforce as a cheap labour source.

METHODOLOGY

Many of the fingerprints on the figurines from Thonis-Heracleion were found on the inside of the figurine, as they were made from two moulded halves that were then joined together. As each of the sheets of clay was pressed into the mould the figurine-makers left behind imprints of their fingers. Once the clay had partially dried it was removed from the mould and then fixed to the other half.

In previous studies objects were directly photographed to document and measure fingerprints, sometimes with more elaborate techniques such as RTI (Bennison-Chapman and Hager 2018), or the fingerprints were measured with a digital caliper (Laing 2022, 356; Sero *et al*. 2021 gives a comprehensive overview of the methods used by existing studies). The difficulty in reaching the fingerprints directly and their fragmentary nature meant that techniques such as measuring finger breadth were not applicable to this material. This study therefore used RTI, which was deemed more suitable for the measurement of fragmentary fingerprints, due to the more sophisticated use of lighting and filters. Direct photography of the imprints was often not possible, therefore mouldable substances such as silicone and plasticene were used to create impressions of the interior of the figurine. These impressions were then photographed using a Nikon DSLR 7100 camera in a 30 cm-diameter RTI dome from FlyDome SAS, with the same distance maintained between the camera and object for all samples, together with a scale in mm. The software Relight was employed for analysis. The RTI images were enhanced in terms of contrast and sharpness using Adobe Photoshop, after which fingerprint ridge density and ridge breadth were measured.

Fingerprint ridge densities were measured either in 25 mm^2 or 6.25 mm^2 squares set diagonally to the axis of the fingerprint ridges being counted (Fig. 3), following the procedure outlined by Fowler (Fowler *et al*. 2022, 333–6). This method was adapted to archaeological material after Acree's 1999 paper which first demonstrated that fingerprint ridge density could be used to distinguish between males and females (Acree 1999). Where possible, the larger 25 mm^2 squares were measured for greater accuracy. In some cases, however, only 6.25 mm^2 squares were available. The value obtained from the 6.25 mm^2 squares was then doubled to be comparable to the larger squares. Both in the case of ridge density and ridge breadth measurements as many measurements were taken as possible to minimize the effect of random errors. Determination of age and sex for each individual was based on the mean of these measurements, as there were no significant outliers in the data.

It is crucial to cross-reference ridge density values to an appropriate modern population, as population-specific differences exist (Sharma *et al*. 2021, 2). Given that many of the figurines from Thonis-Heracleion appear to be Greek imports, it would have been ideal to use modern Greek ridge densities as a reference point; however, in the absence of published studies of the modern Greek population or neighbouring populations this was not possible. Consequently, values for a modern Egyptian population sample were deemed most appropriate. The author's estimates of sex and age were based on established fingerprint ridge densities of modern Egyptians (Wahdan and Khalifa 2017), to account for this variation (Acree 1999, 38). A study of 100 modern Egyptian men and 100 women concluded that the mean ridge density for men in the three regions of the fingers (the three regions being the radial, ulnar and proximal areas) was 11.16/25 mm^2, and 13.84/25 mm^2 for women (Wahdan and Khalifa 2017, 7). The fingerprints on archaeological material are most commonly fragmentary, so it was not possible to determine which area of the finger and indeed even which finger an impression represented. Therefore, an interpretation of the fingerprints was based on Wahdan and Khalifa's mean value of all fingers rather than of a distinct

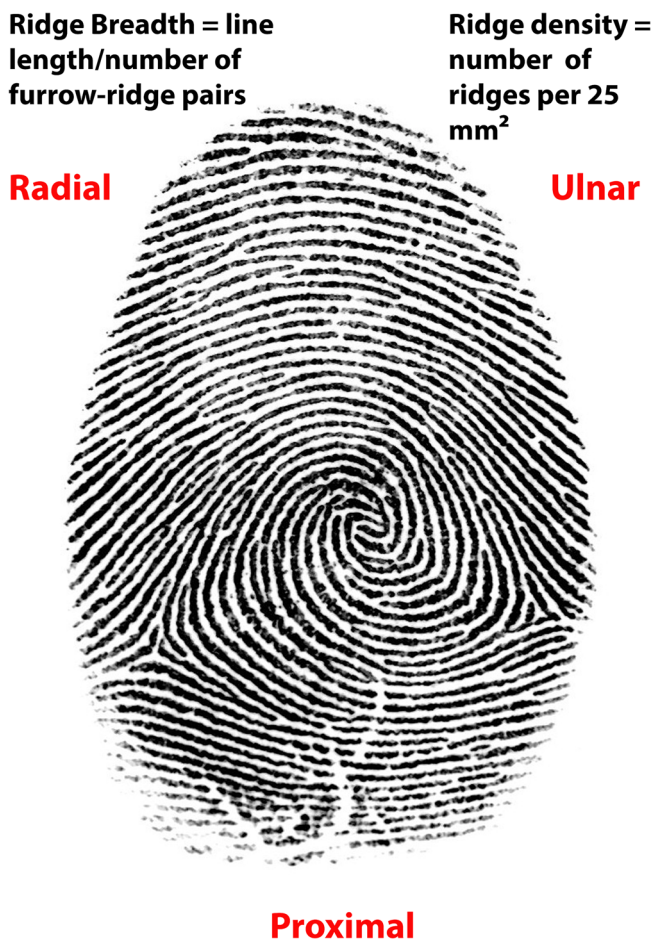

FIGURE 3
Demonstration of the three regions of the finger and the methods for measuring fingerprint ridge density and ridge breadth, after Fowler *et al.* 2019, 1475, fig. 2.

region of a particular finger. Among the modern Egyptian sample population, women were shown to consistently have higher ridge densities for all fingers (Wahdan and Khalifa 2017, 10). A fingerprint ridge density value of >11.87/25 mm^2 was determined as a cut-off value at which the positive predictive value (PPV) was 90.09% for females (Wahdan and Khalifa 2017, 7). Although a recent study of the modern Egyptian population found that there are some differences in the genomes of the modern compared to the ancient population, with modern Egyptian DNA potentially showing greater traces of sub-Saharan influence than their ancestors (Schuenemann *et al.* 2017), there seem to be no major differences in the fingerprint ridge densities of modern Egyptian and modern Sudanese populations (see Ahmed and Osman 2016). Unfortunately, it was not possible to cross-reference the measurements obtained for fingerprint ridge breadth with a modern Egyptian

FIGURE 4
Silicone moulded copy of imprints found on the interior of H20257, including measurements taken for ridge breadths (lines) and ridge densities (squares). Photographs author @ Franck Goddio/Hilti Foundation.

or Greek population, since no studies outlining the average ridge breadths for these two population groups have been published.

Regarding the measurement of ridge breadth, first outlined by Mundorff as a method for sex estimation (Mundorff *et al.* 2014), the number of furrow-ridge pairs was not confined within a defined area as in the case of ridge density. Instead, measurements were taken for the largest area possible over which a line perpendicular to the direction of the ridges was drawn, whose length was then divided by the number of pairs to give an average ridge breadth (Fig. 4). As noted earlier, ridge breadth does not allow distinguishing with great certainty between adult men and adult women. However, pre-pubescent subadults can be clearly determined as having ridge breadths of $<$ 0.39 mm (Králik and Novotný 2003, 5). Likewise, individuals with ridge breadths of $>$ 0.52 mm are likely to be adult males (Fowler *et al.* 2019, 1476).

In addition, the issue of clay shrinkage needs to be considered in an interpretation of the results. Depending on the temperatures at which the clay is fired, the makeup of the clay itself, the presence of mica (inclusions) within the clay, and the duration of the firing process, the terracotta figurines will have slightly shrunk in size along with the fingerprints left behind on them (Laing 2022, 356). A high level of shrinkage would distort the readings of ridge density and ridge breadth towards supposedly higher densities and lower breadths, and would consequently lead to an overrepresentation of young females in the data. A high degree of mica tends to reduce the degree of shrinkage because coarser clays require smaller quantities of water to achieve a pliable condition, and containing fewer clay particles compared with fine clays (Fowler *et al*. 2019, 1489). Quantifying the effect of shrinkage on ridge density and breadth had to be specific for each figurine, as the sample consists of figurines made from a variety of clays and in the case of the Greek imports from likely different origins, utilizing different firing techniques. Other studies from the existing literature have estimated shrinkage rates of 2–7.5%, with some studies opting not to incorporate shrinkage at all (Fowler *et al*. 2020, 8; Kamp *et al*. 1999; Králik and Novotný 2003; Laing 2022; Sanders 2015; Zadeh 2017).

Five of the nine figurines are likely imports from the Greek world with finer clays that would be more prone to shrinkage and were probably fired at higher temperatures than the local Egyptian fabrics. One of the figurines of local origin likely stems from an Alexandrian production centre, utilizing an unusually fine grey clay for Egyptian production which seems to be underfired, as the clay is brittle and disintegrates upon handling (H20258). This particular specimen is unlikely to have been fired at high temperatures given its consistency and should therefore be evaluated at a lower shrinkage rate. In this study, for coarser Nile silt fabrics a lower shrinkage rate of 2% was chosen since the presence of mica lowers the degree of shrinkage and since the local fabrics seem to be less well-fired overall. A rate of 6% was chosen for finer local fabrics. For Greek imports, which tend to be well-fired using very fine clays, a higher shrinkage rate of 7.5% was estimated. Since these shrinkage rates are not certain, sex and age estimates will be given for 0, 2, 6, 7.5% shrinkage-rates, allowing the reader to understand how different shrinkage rates affect the overall estimate (see Tables 2 and 3).

Once measurements had been obtained for both ridge density and ridge breadth, Kamp's equation to estimate the age of the individual was applied (Kamp *et al*. 1999, 312):

$$\text{Age (in months)} = 614 \text{ x Ridge Breadth (in mm)} - 112$$

DISCUSSION

Among the measurements of fingerprint ridge density (Fig. 5, also Tables 2 and 3), ridge densities of >8 and <18 could be observed with a large clustering of values around 11–13, and a notable group at an MRD of 14–18. The group with values of 11–13 most likely represents adults, with those above the cutoff-point of $>11.87/25$ mm^2 determined by Wahdan having a 90% probability of being female (Wahdan and Khalifa 2017, 7). However, this group may also include some males with more characteristically female ridge densities. Those at an MRD of 10 or below can be confidently determined as deriving from adult males. The group of values around 14–18 represents children and adolescents. Pre-pubescent children tend to have higher ridge densities of 15–16+ ridges per 25 mm^2 than adults – albeit uniformly across both sexes, so that a

TABLE 2
Measurements obtained from standard photography for figurines from Thonis-Heracleion and estimates for sex and age of individuals whose fingerprints were found on the figurines; on far-right side the bold font is used to distinguish between different individuals identified on objects

Obj. no	Estimated shrinkage rate based on origin and clay	MRB incorporating respective shrinkage levels	Age estimate in months incorporating respective shrinkage levels	Age in years incorporating respective shrinkage levels	Sex estimate using MRB	MRD incorporating respective shrinkage levels	Sex estimate using MRD incorporating respective shrinkage levels	Evaluation of both estimates
H2795	7.5%	0.58	244.98	20.42	male	11.84	unclear	**Adult male?**
H4076	2%	0.55	227.44	18.95	male	12.74	female	**Adult female?**
H11706 a	6%	0.42	144.80	12.07	N/A	15.04	female/ adolescent	**Adolescent female**
H11706 b	6%	0.49	188.23	15.69	N/A	12.22	female	**Female?**
H18396 a	6%	0.37	131.88	10.99	child	17.13	child	**Child**
H18396 b	6%	0.46	185.57	15.46	N/A	11.75	male?	**Adolescent male?**
H18824	6%	0.64	304.59	25.38	male	9.4	male	**Male**
H20257a	7.5%	0.38	141.32	11.78	child	17.71	child	**Child**
H20257b	7.5%	0.54	249.14	20.76	adult male	12.26	female	**Adult female?**
H20258	0%	0.48	182.90	15.24	N/A	11	N/A	**Unclear**
H20259	7.5%	0.67	334.76	27.90	male	8.70	male	**Adult male**
H20636	7.5%	0.51	228.16	19.01	N/A	12.03	female	**Adult female?**

differentiation between male and female is not possible at this stage in life (Bennison-Chapman and Hager 2018, 117).

As noted earlier, ridge breadth does not allow distinguishing with certainty between adult men and adult women. However, pre-pubescent subadults can be clearly determined as having ridge breadths of < 0.39 mm (Králik and Novotný 2003, 5). Likewise, individuals with ridge breadths of > 0.52 mm are likely to be adult males. Ridge breadth is a good indicator of an individual's age, as ridge breadth increases with age. Among the results from the Thonis-Heracleion figurines (Fig. 6), there is a group of values towards the lower end of ridge breadth, from 0.35–0.37 mm which can be attributed to children and a group towards the higher end at 0.52–67 mm which can be associated with adult males. The measurements from 0.40–0.51 mm cannot confidently be attributed to either sex due to the overlap between male and female ridge breadth. Ages within the group of identified individuals varied, with a larger group around 16–19 years of age, a smaller group of adolescents around 8–14 years of age, and only two individuals at 22 years or older.

As noted earlier, both ridge breadths and ridge densities were measured for each individual as far as possible. However, the sex estimate determined by ridge density was considered more reliable, as ridge densities were cross-referenced against a modern Egyptian population sample, avoiding distortion from measurement differences in ethnic groups, which was not possible in the case of ridge breadth due to the lack of available modern data. If the sex estimate derived from ridge

TABLE 3
Measurements obtained from RTI for figurines from Thonis-Heracleion and estimates for sex and age of individuals whose fingerprints were found on the figurines; on far-right side the bold font is used to distinguish between different individuals identified on objects

Obj. no	Estimated shrinkage rate based on origin and clay	MRB (RTI) incorporating respective shrinkage levels	Age estimate (RTI) in months incorporating respective shrinkage levels	Age in years (RTI) incorporating respective shrinkage levels	Sex estimate using MRB incorporating shrinkage (RTI)	MRD (RTI) incorporating respective shrinkage levels	Sex estimate in years using MRD (RTI) incorporating shrinkage	Evaluation of both estimates (RTI)
H2795a	7.50%	0.55	226.46	18.87	male	11.56	N/A	**Adult male**
H2795b		0.43	152.29	12.69	N/A	14.8	female/ adolescent	**Adolescent female**
H4076	2%	0.57	236.28	19.69	male	12.74	female	**Adult female?**
H11706 a	6%	0.41	139.39	11.62	adolescent?	13.63	female	**Adolescent female**
H11706 b	6%	0.51	200.99	16.75	N/A	12.22	female	**Female?**
H18396 a	6%	0.40	136.65	11.39	adolescent?	15.88	female/child	**Child/ adolescent**
H18396 b	6%	0.50	194.12	16.18	N/A	12.22	female	**Young female**
H18824	6%	0.67	299.72	24.98	male	9.09	male	**Male**
H20257a	7.50%	0.37	114.96	9.58	child	16.19	female/child	**Child**
H20257b	7.50%	0.55	222.75	18.56	male	11.45	N/A	**Adult male?**
H20258a	0%	0.46	168.44	14.04	N/A	10	male	**Adolescent male**
H20258b	0%	0.36	105.97	8.83	child	N/A	N/A	**Child**
H20259	7.50%	0.63	272.49	22.71	male	10.64	male	**Adult male**
H20636	7.50%	0.53	214.38	17.86	male	12.95	female	**Female?**

breadth (possible only for more extreme values) did not agree with the estimate produced by ridge density, the subject was noted as 'tentative'.

Significant discrepancies of ≥0.1 mm in ridge breadth, and ≥5 ridges/25 mm^2 were found on five of the objects (H2795, H11707, H18396, H20257, H20258), which led to the conclusion that these objects contained the fingerprints of multiple individuals. In these cases, the values which could be identified as belonging to each respective individual were averaged separately, as opposed to averaging all the values. For example, H18396 consistently displayed different values of a subadult and a probable adolescent male across various areas of the object, which supports the notion of two separate individuals collaborating. In total, 14 individuals were found to be represented on the nine figurines based on data obtained through RTI.

In terms of quantifying the proportions of female to male figurine-makers, the ratio is similar although there is more evidence for female involvement in figurine-making (Fig. 7). Both men and women seem to have been involved in figurine production for the Greek imports and for the locally produced Egyptian wares (Fig. 8). Notably, a greater quantity of local figurines presents evidence of female involvement compared to the Greek wares, suggesting that at least in the sample that was examined in this study, local females were active participants in figurine

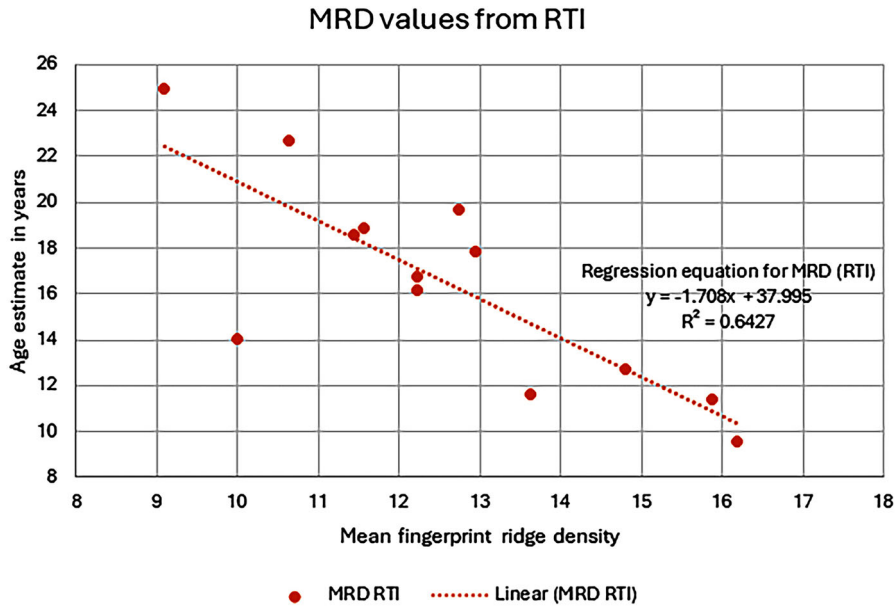

FIGURE 5
Graph demonstrating the results for mean ridge density (MRD) from RTI-images of fingerprints found on the figurines from Thonis-Heracleion. The dotted line indicates the trendline in the data.

production to a greater extent than in Greek figurine production. There is no evidence to support a correlation between the sex of the figurine-maker and the location of the fingerprint impressions, which might occur if certain stages of figurine production had been reserved for either sex (see Table 1 for location of fingerprints). Despite the methodological uncertainties regarding clay shrinkage, the calculation of different shrinkage rates has demonstrated that results obtained from minimal compared to maximal shrinkage in fact only change the estimate outcome for one individual (Table 4), H2795a, for which the sex estimate becomes unclear at the maximal shrinkage. On the other hand, for H20259 shrinkage leads to a clearer sex estimate, demonstrating that overall, even more extreme shrinkage rates of 7.5% did not significantly impact estimates.

The evidence for the involvement of pre-pubescent children is noteworthy. Evidence for the involvement of children was found both on Greek and Egyptian wares, with slightly more evidence for the role of children in local wares. These children seem not to have acted alone in figurine-making but in combination with an adolescent/adult, who was presumably supervising and teaching them. In the five cases where a child was found to be collaborating with an adolescent/adult, both a male and female adult acted as supervisors, so it cannot be said that the role of supervision was restricted to one particular sex. Unfortunately, it was not possible to determine the sex of the children involved, to discern whether perhaps male children were supervised by male adults and similarly for the females. In the case of H11706 where two teenagers were found to be working together, given the small age difference, it is likely that the 'supervisor' was perhaps an apprentice further on into their career or perhaps an older sibling. Likewise in the cases of

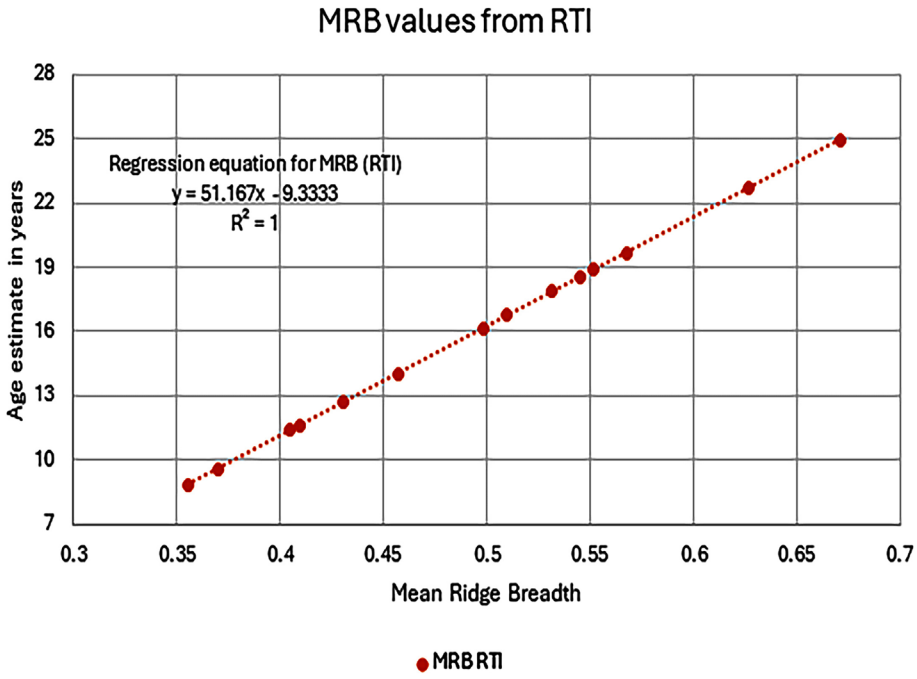

FIGURE 6
Graph demonstrating the results for mean ridge breadth (MRB) from RTI-images of fingerprints found on the figurines from Thonis-Heracleion, plotted against the age estimate in years. The dotted line indicates the trendline in the data.

H18396 and H20258, the age ranges between the young 'supervisor' to the apprentice were very close. H18396, H20258 and H11706 are local fabrics, so perhaps a case can be made that this collaboration of children with adolescents was especially common during this phase of production. Other instances where a child appears to have been involved are H20257 and H2795, both probable Greek imports, where a child or adolescent was paired with an adult male 'supervisor' of around 18 years of age. In contrast to the local wares, in Greek figurine production young apprentices seem to have been paired with slightly older supervisors, representing a difference in the modus operandi of Greek and Egyptian figurine production. So far, there is no evidence for the collaboration of adult men and women, perhaps because figurine-production (at least at the moulding stage where most fingerprints were left behind on the objects) was not sufficiently technical as to require two proficient artisans to work on the same piece.

In terms of contextualizing the results of the present study within previous studies, the results from the figurines from Thonis-Heracleion confirm the notion that child labour formed part of ceramic production, as laid out by Fowler in his work on Bronze Age objects from Israel who likewise found evidence suggesting the involvement of children working together with older individuals (Fowler *et al*. 2019, 1497). Notably, the age ranges of different individuals' fingerprints within the same objects from Fowler's study were similar to those from Thonis-Heracleion. Forte and Miniaci also identified the activity of children in figurine production at Middle Kingdom El-Lahun. However, they did not use Kamp's formula to estimate the ages of the individuals, merely

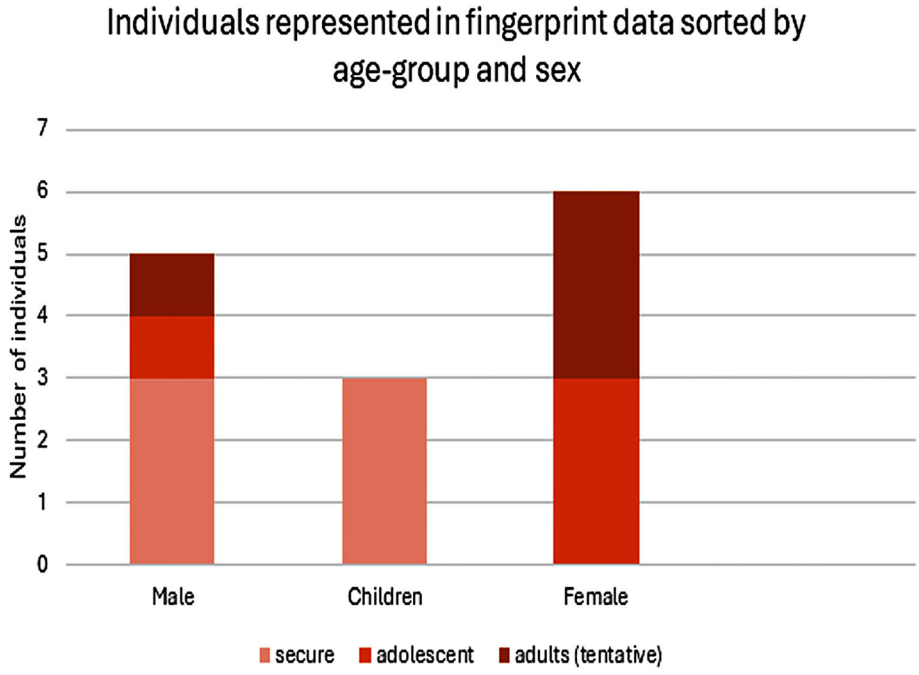

FIGURE 7
Graph showing the numbers of males, females and children represented in the fingerprints found on the figurines from Thonis-Heracleion, based on measurements obtained from RTI. Note that several objects appear to contain fingerprints of multiple individuals, so the number of individuals found in the data is not equal to the number of objects.

using a broad estimate of whether the ridge breadths were indicative of subadult and adult involvement in the production process (Forte and Miniaci 2023, 13). Notably, the material in their study that was associated with children seemed to be mostly composed of animal figurines, with adults being more connected to anthropomorphic figurine production.

Such a distinction of the role of children in the making of animal figurines was not visible in the assemblage from Thonis-Heracleion. But as the group from Thonis-Heracleion involved only a single animal figurine, further trends in the data may yet become apparent as the sample size is expanded. Forte and Miniaci also determined that the figurines from El-Lahun which showed evidence of subadult involvement in the production process were of a notably lower level of skill in terms of production, which they linked to the lower level of experience of these younger individuals (Forte and Miniaci 2023, 19). The material from Thonis-Heracleion which is linked to children does not present any such comparable lower level in skill. However, it is worth noting that children's fingerprints were always found in combination with adult fingerprints, meaning that children were not left to work unsupervised. Any technical mistakes made by the young apprentices may have been corrected by the older 'supervisor'. While a lower level in technical skill would indeed be expected from subadult figurine-makers, it is possible that the role of children in production was restrained largely to pressing the sheets of clay into the moulds and then joining

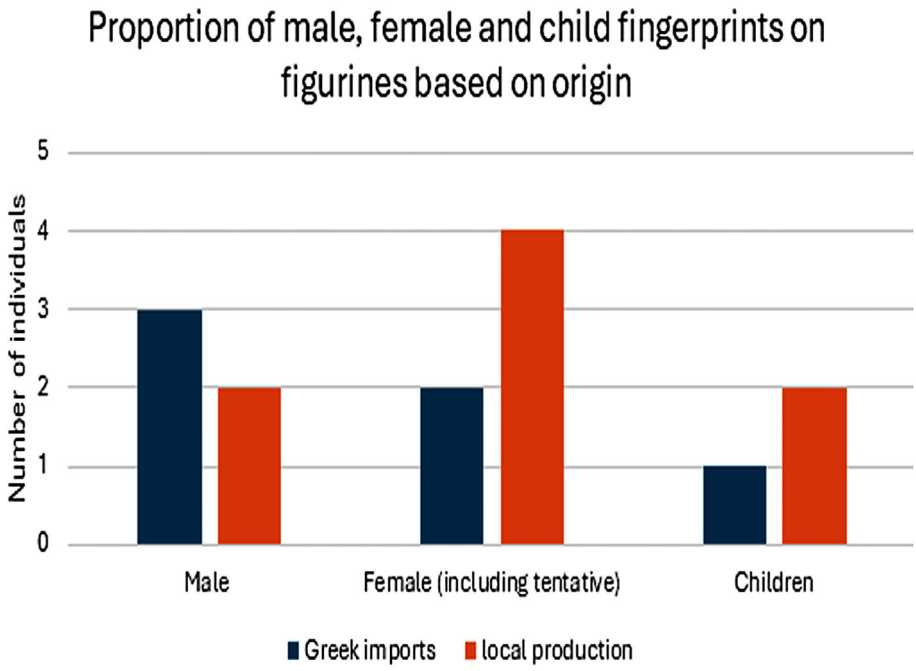

FIGURE 8
Graph showing the numbers of males, females and children represented in the fingerprints found on the figurines from Thonis-Heracleion based on estimated provenance of the object. Note that several objects appear to contain fingerprints of multiple individuals, so the number of individuals found in the data is not equal to the number of objects.

the sheets of moulded clay and not in creating the moulds or in handling the treatment of the exterior surface, which would have required much greater levels of finesse.

Indeed, H20257 which shows the clearest fingerprint impressions among the assemblage supports this idea of child apprentices having been given lower-level tasks in figurine production. The impression of three fingers from the interior of the figurine, presumably left behind when pressing the clay into the mould, appears to derive from a child or young female. However, the figurine's base was also found to contain the fingerprints of an adult, and the reverse only contained adult impressions, which may illuminate the role of children in this figurine's production – perhaps child apprentices were considered to be particularly suited to pressing the clay into the moulds, since this function required relatively little finesse compared to handling the visible exterior surface on which fingerprints were presumably not desired. Removing the clay from its mould and attaching the two halves without damaging either the shape or the details of the moulded clay would have presented a more difficult stage, where significant errors might have required a complete overhaul of the particular piece. It is also possible that children's hands with their smaller size were more suitable for pressing the clay into the moulds. In any case, the findings strongly suggest the involvement of children in figurine production, as a cheap and readily available source of labour.

TABLE 4
Differing age and sex estimates for figurines depending on shrinkage rates, based on RTI measurements

Obj. no	Ridge breadth mean (MRB) as observed	Ridge density mean (MRD) as observed	sex estimate at 0% shrinkage	age estimate (in months) at 0% shrinkage	age estimate (in years) at 0% shrinkage	MRD at 2% shrinkage	sex estimate at 2% shrinkage	age estimate (in months) at 2% shrinkage	age estimate (in years) at 2% shrinkage
H2795a	0.51	12.50	**female?**	202.85	16.90	12.25	**female?**	209.14	17.43
H2795b	0.40	16.00	**child**	133.86	11.15	15.68	**child**	138.77	11.56
H4076	0.56	13.00	**female**	229.45	19.12	12.74	**female**	236.28	19.69
H11706a	0.39	14.50	**child**	125.16	10.43	14.21	**child**	129.90	10.83
H11706b	0.48	13.00	**female**	183.27	15.27	12.74	**female**	189.18	15.76
H18396a	0.38	16.89	**child**	122.57	10.21	16.55	**child**	127.26	10.61
H18396b	0.47	13.00	**female**	176.79	14.73	12.74	**female**	182.57	15.21
H18824	0.63	9.67	**male**	276.41	23.03	9.47	**male**	284.18	23.68
H20257a	0.34	17.50	**child**	99.12	8.26	17.15	**child**	103.34	8.61
H20257b	0.51	12.38	**female**	199.40	16.62	12.13	**female**	205.62	17.14
H20258a	0.46	10.00	**male**	168.44	14.04	9.80	**male**	174.05	14.50
H20258b	0.36	N/A	**no MRD, MRB suggests child**	105.97	8.83	N/A	**no MRD, MRB suggests child**	110.33	9.19
H20259	0.58	11.50	**unclear**	245.66	20.47	11.27	**unclear**	252.82	21.07
H20636	0.49	14.00	**female**	191.59	15.97	13.72	**female**	197.66	16.47

Obj. no	MRD at 6% shrinkage	sex estimate at 6% shrinkage	age estimate (in months) at 6% shrinkage	age estimate (in years) at 6% shrinkage	MRD at 7.5% shrinkage	sex estimate at 7.5% shrinkage	age estimate (in months) at 7.5% shrinkage	age estimate (in years) at 7.5% shrinkage
H2795a	11.75	**female?**	221.74	18.48	11.56	**Unclear from MRD, MRB suggests male**	226.46	18.87
H2795b	15.04	**child**	148.61	12.38	14.80	**child/adolescent**	152.29	12.69
H4076	12.22	**female?**	249.94	20.83	12.03	**female?**	255.06	21.26
H11706a	13.63	**child/adolescent**	139.39	11.62	13.41	**child/adolescent**	142.94	11.91
H11706b	12.22	**female**	200.99	16.75	12.03	**female**	205.42	17.12
H18396a	15.88	**child**	136.64	11.39	15.62	**child**	140.16	11.68
H18396b	12.22	**female?**	194.12	16.18	12.03	**female?**	198.45	16.54
H18824	9.09	**male**	299.72	24.98	8.94	**male**	305.54	25.46
H20257a	16.45	**child**	111.79	9.32	16.19	**child**	114.96	9.58
H20257b	11.63	**female?**	218.08	18.17	11.45	**female?**	222.75	18.56
H20258a	9.40	**male**	185.27	15.44	9.25	**male**	189.48	15.79
H20258b	N/A	**no MRD, MRB suggests child**	119.05	9.92	N/A	**no MRD, MRB suggests child**	122.32	10.19
H20259	10.81	**male**	267.12	22.26	10.64	**male**	272.49	22.71
H20636	13.16	**female**	209.80	17.48	12.95	**female**	214.36	17.86

CONCLUSIONS

This study has been one of the first to work with paleodermatoglyphics from the Mediterranean, and the first to work on material of the Late and Ptolemaic periods. The study has demonstrated that the effect of shrinkage is in fact not as significant as anticipated. The results of the present study demonstrate that men, women, and children were involved in figurine-production cross-culturally across Egypt and Greece. While little is known about the social standing of figurine-makers in Ancient Egypt, from this study it becomes clear that the workload was shared between both sexes, perhaps even among a whole family. Among the Greek imports, men tend to be more represented than women which is in line with the view of coroplasts given by ancient writers, although the evidence also shows that figurine production in Greece was not an all-male profession either. The greater presence of women involved in local production may imply a difference in the *chaîne opératoire* of Greek compared to Egyptian figurine production, in addition to the greater collaboration between adolescents and children. Notably, differences in the locations on the figurine for children's compared to adult fingerprints were visible in the evidence, reflecting the training process of the younger workers, whose role seemed to be restricted to simpler tasks.

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Institute of Archaeology
36 Beaumont Street
Oxford OX1 1AB
UK
E-mail: leonie.hoff@hmc.ox.ac.uk

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