DISCOVERING CHILDHOOD: USING FINGERPRINTS TO FIND CHILDREN IN THE ARCHAEOLOGICAL RECORD

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Experimental replications show that ridge breadth measurements from fingerprints on archaeological artifacts can be used to estimate the age of the individual who produced the prints. While the greatest amount of variability in human ridge breadth is due to the growth during development from birth to adulthood, there is also variability due to hand and body size, sex, and ethnicity. Despite these confounding variables, the variability due to age is great enough to allow the separation of children’s prints from those of adults using ridge breadths. The utility of this measurement is illustrated with a short case study using ceramic vessels and figurines from northern Arizona. This discovery has great potential for illuminating some of the roles that children played in prehistory.

Réplicas experimentales muestran que las medidas de los cordones de huellas digitales en los restos arqueológicos sirven para estimar la edad del individuo que produjo las huellas. Mientras que la variación más amplia en los espacios de cordones se deben al crecimiento durante el desarrollo entre el nacimiento y la edad adulta, hay variación también debida al tamaño de la mano y el cuerpo, al sexo, y a la etnicidad. A pesar de estas variaciones confusas, la variación por causa de la edad es tanta que se puede distinguir las huellas digitales de niños de las de adultos. La utilidad de la medida es ilustrada con un breve estudio usando vasos y estatuillas cerámicas del norte de Arizona. Este descubrimiento tiene potencial enorme para iluminar algunos de los roles que los niños tuvieron en la prehistoria.

Occasionally fingerprints are found on prehistoric clay figurines, ceramics, wall surfaces, and pictographs. Ridge breadth measurements from these prints can be used to estimate the age of the producer. Experimental data show that, even when prints are partial and neither the finger nor the finger portion which they represent can be identified, the high correlation between age and ridge breadth allows an estimation of the age of the producer sufficient for separating adults’ prints from those of children. This opens the possibility of investigating issues such as the participation of children in ceramic manufacture.

By the seventh month of natal development, the dermatoglyphic patterns of the fingers are complete, and no further modifications occur during maturaion (Holt 1968:6). Since during growth the overall size of the hands increases, the fingerprints increase in size without adding new ridges, and ridge breadth, defined as the measurement from the center of one ridge across the ridge to the center of the next furrow (Penrose 1968), increases.

Physical anthropologists have not studied ridge breadth to the extent that other fingerprint characteristics such as ridge patterns and number of ridges have been investigated (David 1981). Nevertheless, evidence does point to systematic relationships between ridge breadth and sex (Cummins et al. 1941; Jantz and Parham 1978; Penrose and Loesch 1967), hand size and adult body size (Cummins et al. 1941; Ohler and Cummins 1942), and ethnicity (Jantz and Parham 1978; Kamali 1984). These variables, of course, tend to be inter-related, since some of the variability in hand and body size can be explained by both sex and ethnicity.

Within a single individual, the breadth of fingerprint ridges varies within the hand and between hands, but the differences are quite small—on the order of 0.5 mm and less (Cummins et al. 1941). The ridges in the palm area tend to be a bit coarser than those on the fingertips. On the fingertips, the thumb has the coarsest ridges, while those of the ring finger are finest. In general, the right hand has somewhat coarser ridges than the left, but this is not true for all the fingers, nor for every individual.

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Males’ ridge breadths tend to be larger than females’ (Jantz and Parham 1978; Penrose and Loesch 1967). The differences between the average ridge breadths of males and females appears sometime during puberty (Loesch and Czyzewska 1972). Some, but not all, of the disparity may be due to differences in body size. Jantz and Parham (1978, Table 1 based on their own research and previously published data from Penrose and Loesch 1967 and Katznelson and Ashbel 1973) report differences of around .05 mm between males and females of English, Ashkenasi Jewish, and Yoruba extraction. In other populations, sex differences appear to be even more minor. For example, Micle and Kobylianski (1987) report only a .02 mm ridge breadth difference between males and females for a sample of 240 Yemenite Jews.

Ridge breadths differ more between regional populations than between males and females from the same population. Studies of palmar ridge breadths, which tend to be a bit larger than finger ridge breadths, show variability of as much as .3 mm between ethnic groups, with a range of average breadths for adults between approximately .5 mm and .8 mm for most populations world wide (Jantz and Parham 1978; Kamali 1984; Micle and Kobyliansky 1987). Part of the variability between ethnic groups is due to differences in average body size, but this relationship is made more complex by the fact that average ridge counts also vary between ethnic groups and some ethnic groups appear to have fewer, but wider, ridges on a similarly-sized hand (Leguebe and Vrydag 1982; Jantz and Parhan 1978).

The greatest variability in ridge breadth is due to age. An early study by Hecht (1924) showed a range of average ridge breadths from .15 mm in premature newborns to .5 in adult males. Ridge breadth increases fairly rapidly until sometime during the teenage years, presumably around the time that growth begins to slow down. David (1981) compared average ridge breadths of groups of males aged 4 to 7, 8 to 11, 12 to 15, 16 to 19, and 20 and above. There were significant differences between the average ridge breadths of all the adjacent age groups except the last two. Ridge breadths of 16- to 19-year-old males were not significantly different from those of males 20 and above.

Research on ridge breadth suggested to us that ridge breadth measurements from archaeological specimens might be useful for estimating the age of the individual who produced them. We have conducted a series of experiments to test this idea and to develop a method for estimating age from ridge breadth measurements. Previous research has concentrated on the comparison of age groups. While this is adequate for demonstrating significant changes in breadth through development, it does not allow prediction. For this, a regression equation is more useful. Furthermore, previous studies do not assess other issues important to archaeologists, such as the effects of clay shrinkage on ridge breadth measurements or the effect of possible biases when it is not possible to control for either finger or finger portion.

**Experimental Replications**

To determine the relationship between age and ridge breadth, we examined fingerprints produced in two ways: by rolling inked fingers on paper and by producing small clay figurines similar to those found archaeologically. The goal of the research was to produce regression equations for predicting age using an average ridge breadth measurement. To assess the effects of shrinkage on fingerprints impressed in clay, we also had some subjects produce prints on clay tablets.

As mentioned previously, ridge breadth is often determined by measuring from the center of one furrow across the ridge to the center of the next furrow (Penrose 1968). Because of the difficulty of positioning a calipers exactly on the center of a three-dimensional ridge, we used an alternative strategy, measuring from the beginning of one ridge across the ridge and furrow to the initiation of the next ridge. As with Penrose’s method, this provides a measurement of one ridge and furrow pair. For consistency, the measurement should always be done perpendicularly across the ridges. Accuracy was increased by measuring multiple ridge breadths simultaneously, then dividing by the number of ridge-furrow pairs.

Fingerprint specialists specify an exact portion of the finger or palm and take all their measurements from exactly the same location. For example, Penrose and Loesch (1967) suggest measuring the distance between the a and b triradii, then dividing by the number of ridges to produce a ridge breadth measurement. Archaeologically, this exactness is not possible because the prints tend to be partial and the portion of the finger or palm is not usually identifiable. A more feasible archaeological alternative is to
measure the maximum number of ridge-furrow pairs possible and divide the distance by the count. Instead of restricting data to prints from certain portions of the finger, all visible prints were used.

Calculating ridge breadths for the inked prints was fairly straightforward. We counted 10 ridges from immediately above the central whorl toward the periphery and measured the distance from the initiation of the first ridge to the termination of the furrow for the tenth ridge. Note that this corresponds to the point of initiation for the eleventh ridge. The total distance was then divided by 10 to produce a figure for the ridge breadth.

Prints in the clay were more difficult to measure, particularly on the archaeological specimens. We stabilized the figurine near a good light source, then, to increase visibility, used a 10-power hand lense to magnify the print being measured. We measured as many ridge-furrow pairs as possible and divided the total measurement by number of pairs. It should be noted here that the ridges of prints impressed in clay are the equivalent of the furrows on the finger itself.

All measurements were taken with a digital calipers which measured to .01 mm. Since measurements were initially taken for multiple ridge-furrow pairs, then divided by the number of pairs, ultimately ridge breadth measurements were calculated to three decimal places. This is undoubtedly well beyond the actual level of precision of the measurement, so we rounded to two decimals. The main source of error will be the exact positioning of the calipers. We have not done the repeated measure studies that would provide data on the amount of inter- and intra-observer error that can be expected. Some standardization was achieved in this study by having a single individual take as many of the measurements as possible. Nicole Timmerman measured fingerprints on the inked prints and experimentally produced figurines. Gregg Lind measured fingerprints on clay tablets for the shrinkage study, and Kathryn Kamp and John Whittaker measured fingerprints on the archaeological specimens.

Inked fingerprints were obtained from 107 individuals aged 36 months to adult. This total includes prints from 34 individuals donated by Richard Jantz of the University of Tennessee. The rest are from Grinnell College students and residents of the town of Grinnell, Iowa. Although there was some ethnic diversity in the sample, the participants were primarily of predominantly European backgrounds. Because it is not usually possible to determine either the exact finger or finger portion on archaeological specimens, we averaged ridge breadth measurements for all 10 fingers to produce a mean ridge breadth. Because growth stops at around age 22 or before, we truncated the adult ages at 264 months. The mean ridge breadth for an average of all 10 fingers correlated very strongly with age in months (r = .87).

The strong relationship between age and ridge breadth is undoubtedly due, at least in part, to the marked increases in body size that occur between birth and adulthood. These can easily be measured in terms of either height or weight. An initial examination of the 40 fingerprints provided by Jantz showed high correlations between age in months and both height (r = .97) and weight (r = .94). Obviously, such an extremely high correlation is because we are comparing very small children with adults. Within an age group the correlation would be much lower. The higher correlations in this small sample of data were also due, to an extent, to an under-representation of certain age groups. In the initial 40-person sample, the correlation between ridge breadth and height also was high (r = .94), the same as for the relationship between ridge breadth and age. However, the correlation between ridge breadth and weight was lower (r = .88). From this outcome, we concluded that ridge breadth might be a good predictor of height but would probably be a less accurate predictor of weight. Because height estimates are less sensitive to obtain as well as probably more highly correlated with ridge breadth, we decided to ask the participants in our study to provide their heights, but not weights. The correlation between height and inked ridge breadth for all 107 participants was .84, comparable to the relationship between age and ridge breadth. Thus, it appears that ridge breadths can be used to estimate either height or age, if a full set of prints is obtained from each individual.

The fingerprints found on archaeological specimens, unfortunately, do not occur in complete sets. Furthermore, it is a likely that certain fingers and finger portions are preferentially represented. Based on casual observations, it appears that the tips of the fingers and the first three fingers of whichever hand is dominant produce a higher percentage of the prints. This calls into question the potential validity of equations for predicting age based upon ridge breadth produced using complete sets of fingerprints. To investigate the possibility that the haphazardly-pro-
duced fingerprints from figurines and ceramic vessels could also be used to predict age, we had 101 individuals aged 65 months to adult each make a small clay figurine, similar to those found in many archaeological sites in the American Southwest. The age distribution of the subjects is fairly flat, although there is some under-representation of the 8 to 11 year old group and over-representation of the 12 to 13.5 year old group (Figure 1). Ridge breadth measurements were taken from as many fingerprints as possible and a single value was obtained for the entire figurine by averaging the measurements for the prints.

Again, very high correlations between both age and ridge breadth ($r = .85$) and height and ridge breadth ($r = .87$) were obtained. For some age groups the spread of ridge breadths is greater than for others (Figure 2). Particularly, around puberty (ca. 150 months) the spread becomes very large, perhaps reflecting differences in growth patterns. The relationship between height and ridge breadth (Figure 3) does not show the same nonconformity.

The regression equation for predicting age from ridge breadth that our experimental figurines yields is: $\text{Age (in months)} = 614 \times \text{Ridge Breadth (in mm)} - 112$. If ridge breadth measurements are used to estimate age, the margin of error for the 95 percent confidence intervals for the prediction of individuals is about 4.5 years, while that for the prediction of a mean age for a group of individuals based on an average of the ridge breadths from a sample of artifacts or individuals is less than a year. This type of precision would easily allow researchers to suggest that some artifacts were probably produced by adults and others by children. The inferences would be particularly strong when grouped measurements on a fairly large sample of artifacts were analyzed. The assumption then, of course, is that the group producing the prints is fairly homogeneous. The equation for predicting height from ridge breadth is $\text{Height (in cm)} = 243 \times \text{Ridge Breadth (mm)} + 41.1$. If age estimates are the desired outcome, heights must then be translated into age using a knowledge of local population variability in height.

The potential effects of clay shrinkage also need to be assessed before fingerprints impressed in clay artifacts can be analyzed. Shrinkage must be evaluated either when predicting age directly from archaeological fingerprints, using a regression equation such as the one we have produced or comparing prints from two different types of artifacts from the same site. It should be noted, however, that if two different types of artifacts made with the same paste are being compared merely to determine whether or not they were produced by the same group, it is not necessary to consider the effects of shrinkage. Thus, if the same clay and temper mixture is used both to produce molded clay objects and ceramic vessels, a comparison of the average ridge breadth of fingerprints on surfaces from a sample of each type of artifact will reveal whether or not the two artifact types are being produced by the same group of individuals. For this simple question, shrinkage does not have to be considered, because the effects of shrinkage will be the same on both artifact types.

For ease of production, we had subjects make the clay figurines using a commercial art clay obtained from the Art Department at Grinnell College. Initially, we tested a sample of prints before and after drying and firing, and found no significant differences in ridge breadths. This may be because the clay was especially formulated to minimize shrink-
Figure 3. Relationship between heights of the figurine producers and the average ridge breadths of prints left on the figurines.

Figure 4. Boxplots showing a comparison between the average ridge breadths of prints from Sinagua figurines and Sinagua corrugated vessels. The central 50 percent of the data is contained in the box; the median is indicated by the center line; exterior lines show the range of values.

Age. In order to assess shrinkage effects in clays more similar to those found archaeologically, we measured 105 fingerprints impressed on clay tablets 1) when wet, 2) after drying, and 3) after firing. The tablets were produced to replicate Sunset Brown, a Northern Sinagua Alameda Brown Ware (Colton 1955, 1958), as closely as possible. Sinagua area clays were ground using a mano and metate, mixed with fine volcanic cinders in a 4:1 ratio by volume, then moistened with water and kneaded. The tablets were fired for 3 hours at 800°C to simulate a low, fast fire. Shrinkage after the initial drying was about .05 mm, significant at the .001 level. The amount of shrinkage between drying and firing was very slight (.002 mm) and not statistically significant.

An Archaeological Test

The Sinagua also made a variety of brownware ceramics (See Colton 1955, 1958 for more description of Sinagua ceramics). Since the vessels were produced for cooking, storage, and other adult uses, and are often of very high quality, it is likely that most (although perhaps not all) of them were produced by adults. While potters may begin to learn their craft as children, the majority of vessels in ethnographically-known pottery-producing societies are shaped by adults. Most of the Sinagua types are smoothed and frequently burnished as well, so they do not often preserve fingerprints. The corrugated vessel types, Elden Corrugated and Sunset Corrugated, are exceptions. Fingerprints are often preserved in the corrugations. Since it is likely that most of these vessels were produced by adults, we expected them to provide a nice contrast to the figurines.

The Sinagua were an ancestral Puebloan group in northern Arizona. Figurines and corrugated clay vessels from the Sinagua area provide data for a case study in the use of fingerprints for estimating age. Small locally-made animal figurines are found in most Sinagua sites. While they are usually found in Fill, they are occasionally associated with child burials (Kamp and Whittaker 1999:60; Schaefer 1986:424–425), which suggests that they may be toys. There is considerable morphological variability, but most figurines tend to be rather crude. The surface is often lumpy, the shapes rarely include much detail, and appendages such as legs and tails are often poorly attached. While these patterns certainly do not prove that the figurines were made by children, they are suggestive (See Kamp and Whit-taker 1999 for a further discussion of Sinagua clay figurines).
breadths of .42 for the figurines and .54 for the corrugated vessels. The corresponding average ages are 12 for the figurines and 18 (adult) for the corrugated vessels with a margin of error of less than a year. This implies that the average age of figurine makers was between 11 and 13. The range of ages for producers of the fingerprints on figurines is 4 years to adult (with a 95 percent confidence interval margin of error of about 4.5 years). Thus, the figurines with the smallest prints were made by children between birth and 8.5 years, while those with the largest prints were produced by adults, perhaps parents, other caregivers, or simply a friendly potter. For the ceramic vessels, while the average potter was an adult, the age range suggested for individuals is 10 years to adult, again with a margin of error of about 4.5 years.

Using this approach, we can conclude that while adults are producing most of the ceramic vessels, children are making most of the animal figurines. The average ridge breadth values for the figurines are securely in the child range. Furthermore, the ridge breadths for some of the figurines are so small that it is highly unlikely that they are from adult fingerprints. Nevertheless, some of the ridge breadths from figurines are within the adult range. It may be that these are, in fact, the result of adults manufacturing some of the figurines, while children are making others or it may be that the larger fingerprints are from older children. The corrugated vessels, on the other hand, appear to be made primarily by adults, although the range of producers included some children. Several rather sloppily-made vessels had smaller ridge breadth values and may represent children who are still in the learning stages.

Theoretically, we could also have used a regression equation to predict heights from the ridge breadths and from the heights infer ages. However, when height estimates were calculated using our regression equation, they seemed too high even for adult Sinagua populations. We obtained an estimated average height of 171 cm (about 5'7") for the vessel producers. Previous stature estimates, based on archaeological samples suggest that, like most prehistoric Southwestern populations, the Sinagua tend to be short in comparison to modern U.S. populations (Bartlett 1941; Kamp and Whittaker 1999). The figure is at the very high end of height averages for males. The closest Southwestern figure we could find was from Pueblo Bonito where the males averaged 169.3 cm (Akins 1986: 136). This may suggest that, if our heights are overestimated, so are our ages.

This disparity between the conclusions reached using the two equations point to potential problems in using a regression equation obtained for one ethnic group for the prediction of parameters for a second, not closely-related group. Skeletal stature estimates are calculated using equations like Trotter and Gleser (1958) or Genoves (1967), neither of which were derived using historic native Southwestern populations. Similarly, the equation we derived for estimating age using ridge breadth was not based on data from the target population. It suggests that while the use of a regression equation may be suggestive, the real strength of the method is in the comparison of artifact assemblages within a single cultural unit, so that there is control for ethnic variability.

**Conclusions**

Experimental evidence shows that the ridge breadth measurement from fingerprints can be used to estimate age. Nevertheless, variability in ridge breadth is affected by hand and body size, sex, and ethnic affiliation in addition to age, and the interrelationships between these three variables are complex. Thus, while age has the largest effect upon ridge breadth, ethnic affiliation, sex, hand size, and adult body size also influence ridge breadths. Obviously the multiple factors involved in ridge breadth make it more difficult to argue that differences in ridge breadth are due solely to variability in the age of the producers. Ethnic affiliation is a particularly salient problem. Nevertheless it can be controlled by comparing ridge breadth measurements from different types of artifacts from the same site, where there is some certainty of relative ethnic homogeneity.

While sex differences in ridge breadth are not insignificant in some populations, the magnitude of the difference is small enough that the effect would tend to be swamped by age differences. Archaeologically, because the difference between male and female ridge breadths tends to be small and because there are also differences in ridge breadth due to age, hand size and adult body size (Cummins et al. 1941; Ohler and Cummins 1942) and ethnicity (Jantz and Parham 1978; Kamali 1984), that cannot be controlled, it would be very difficult to make a case for the notion that a particular fingerprint or set of prints was produced by a woman, rather than a man.
Again, the best procedure may be to compare average ridge breadth values for one artifact type to those from another. Average differences that are small, perhaps in the vicinity of .05 mm or less may well be due to differences in the gender of the producers, while larger differences are more likely to be due to differences in the age or ethnicity of the producers. When ethnicity is likely to be homogeneous, age differences are likely to be the cause of any large disparities in ridge breadth measurements. It is also likely that the variability across ethnic groups is not so great that very small ridge breadths (those below .35 or perhaps below .4) cannot almost invariably be attributed to children, rather than adults.

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