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Digit ratios among the modern population of the Canary Islands

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SUMMARY

Sexual differences in the index to ring finger length ratio (2D:4D ratio) have been observed since more than 150 years ago, and they are already present in the foetus. Homeobox genes, which also control the differentiation of testes and ovaries, are involved in finger conformation, which is subjected to the influence of testosterone and estrogen levels. In general, women show larger 2D:4D digit ratios, although differences between sexes are subjected to ethnic variations. This study was performed in order to analyse the absolute values of several digit ratios (2D:4D; 4D:3D; 2D:3D) among 164 young adults of Tenerife (101 women). Finger lengths were directly measured dorsally using a calliper with an accuracy level of 0.01 mm. Dorsal digit lengths were defined as the distance between the fingertip and the dorsal base of the proximal phalanx, in a position in which fingers and palms formed an angle of 90º. We found that 2D:4D of both hands (for instance, women=0.9631 ± 0.02647; men= 0.9535 ± 0.02507 for the left 2D:4D ratios), the left 2D:3D (0.9063 ± 0.02216 in women; 0.8980 ± 0.01931 among men) and the right 4D:3D ratios (0.9377 ± 0.03625 among women *vs* 0.9471 ± 0.02138 among men) were significantly different among men and women. The magnitude of the difference among sexes is similar to that reported for other populations, and they allow for the elaboration of a discriminant function with an accuracy of 60.4%, that reaches 86% if stature is also included. We applied this discriminant function to a test group composed of 36 randomly selected women and 24 men, obtaining an accuracy of 58.33% and 81.67%, respectively.

Key words: Digit ratio – Sexual dimorphism – Canary Islands population

INTRODUCTION

Assessment of sexual dimorphism is a widely investigated subject, since it has important implications in forensic medicine and anthropology. Sexual assignment of dispersed human remains can be achieved using a wide spectrum of procedures, ranging from genetics to pure anthropometric measurements. Although skeletal dimorphism is clearly evident in pelvic bones, and also in several parameters obtained from long bones and many other bones or teeth, usually combined in discriminant functions (Iscan and Miller-Shaivitz, 1984), differences are less evident in other parts of the body, such as hands. Sexual differences in the index to ring finger length ratio (2D:4D digit ratio) were observed more than 150 years ago (Ecker, 1875), and are already present in intrauterine life (Phelps, 1952). In the past two decades, several studies have pointed out that these differences are driven by the Homeobox genes, which also regulate the differentiation of testes and ovaries (Kondo et al., 1997). The values of 2D:4D ratios should depend on the intrauterine exposure of the developing finger to testosterone and estrogen levels (Lutchmaya et al., 2004), both of fetal and mater-

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nal origin, although this dependence is not universally accepted (Hampson and Sankar, 2012). Moreover, in some populations no differences in the digit ratios are detected (Evardone and Alexander, 2009; Kumar et al., 2017; Apicella et al., 2016), whereas in others the differences are striking (Gorka et al., 2015). Therefore, in addition to the eventual intrauterine exposure to sex hormones, it seems that there must be also a genetic background, and because of this, it is important to assess whether or not there are differences among sexes in several different population groups.

As mentioned previously, in most studies men and women show different values of the 2D:4D ratio. It is usually greater among women than among men (1 vs 0.98 in the early report by Manning et al, 1998), but there are different results according to ethnicity (Manning et al., 2007; Xi et al., 2014), and also variations according to the method employed for measuring finger lengths (Manning et al., 2005; Vehmas et al., 2006). Many authors have analysed the relationship of this ratio with several traits of “masculinity” or “femininity” (Evardone and Alexander, 2009), with muscle strength (Ribeiro et al., 2016; Tomkinson and Tomkinson, 2017), with sexual behaviour (Robinson and Manning, 2000), or with reproductive success (Manning et al., 2000; Manning and Fink, 2008). Others have tested its clinical value as a diagnostic aid in some situations in which the developing foetus could be exposed to altered testosterone levels (Brown et al., 2002; Jeevanandam and Muthu, 2016), and others have hypothesized that variations in the 2D:4D digit ratio might predispose to several diseases (Manning and Bundred, 2000), including osteoarthritis (Ferraro et al., 2010).

However, as reported, there are also variations according to ethnicity –as it happens with many other dimorphic features–, and to the method employed. It is therefore important to gather information about the values of the 2D:4D digit ratio in different populations of the world. To our knowledge, this ratio has not been assessed among the modern population of the Canary Islands. Therefore, the aim of this study is to analyse the eventual differences in 2D:4D, 2D:3D and 4D:3D ratios among men and women of Tenerife, an island of the Canary Archipelago, whose population consists of a mixture of Spaniards, Portuguese and other European ancestors with the Guanches –the indigenous population that inhabited the island before the Spanish conquest.

MATERIALS AND METHODS

The study included two different samples, a study sample and a test sample. The study sample was composed of 164 individuals (101 women and 63 men) with a mean age of 21.80±4.68 years (median 21, interquartile range 19-23 years), all of them students at the medical school of the University of La Laguna (Tenerife). Individuals were selected if there was no history of hand injuries, deformity or arthrosis, and if they gave informed consent to participate in the study.

Body mass index (BMI) was calculated combining stature (self-reported in many cases, assessed by a stadiometer when the individuals were unsure about it) and weight (self-reported o directly weighed if the individual did not know his or her weight), as

$$BMI=Weight (Kg)/Stature (meters).^2$$

For digit length measurement we followed the method described by Kumar et al. (2017). Briefly, digits were directly measured dorsally using a digital calliper with an accuracy level of 0.01 mm. Dorsal digit length was defined as the distance between the fingertip and the dorsal base of the proximal phalanx, in a position in which fingers and palms formed an angle of 90º (Fig. 1). The ring finger, index finger and middle finger were measured this way, and the corresponding digit ratios were calculated (and expressed as 2D:4D; 2D:3D, and 4D:3D ratios). In addition, we measured the length of the proximal phalanx of the three mentioned fingers, and calculated the proximal phalanx/total length indices for each of the mentioned fingers.

The test sample was selected in order to determine if the obtained discriminant function served to separate sexes among the living population of Tenerife, whatever age or stature. Inclusion criteria were the same described for the study group, but the population included individuals with variable ages, who were selected among students, teachers, and workers at the Hospital Universitario de Canarias (associated to the medical college of the University of La Laguna), comprising 24 men and 36 women, with a wide age range (median age 29; IQ=26-43.5 years).

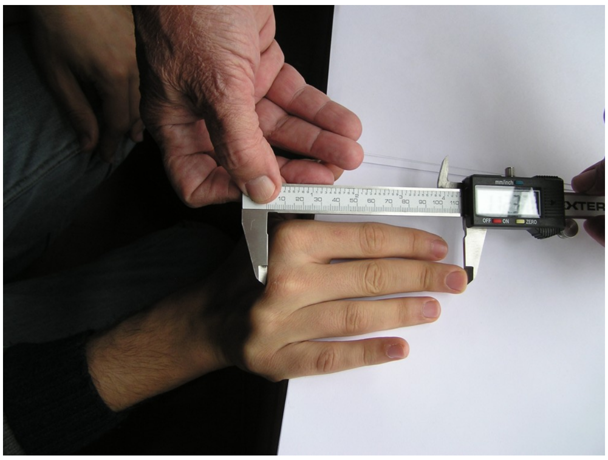

Fig 1. Measurement of finger length.

Statistics

First, we tested whether the digit ratios or BMI were normally distributed or not, by means of Kolmogorov-Smirnov test. If variables showed a parametric distribution we used Student's t test to compare their means among sexes (or Mann-Whitney´s U-test if we order the individual values hierarchically); if the distribution was not parametric we used Mann-Whitney´s U test for comparisons among sexes. If we wanted to analyse whether there was a relationship among two parametric variables, we used Pearson's single correlation test, or Spearman's test if the analysed variables showed a non-parametric distribution. If there were two or more variables related to a third variable and we wanted to know which of them was independently related to the third one, we utilised multiple regression analysis. With those digit ratios that showed differences among sexes in the univariate analysis we performed both a logistic regression analysis, in order to discern which of the digit ratios was independently related to sex, and discriminant function analyses, that were then applied to a test group. Other discriminant function analyses were also performed including stature or finger lengths. These discriminant function analyses were then applied to the test sample. All the statistical analyses were made using SPSS 15.0 software (Chicago, Illinois, USA).

RESULTS

We included 164 individuals, 101 women and 63 men aged 22.20±5.53 and 21.17±2.75 respectively. Most of them (149) were right handed.

BMI

BMI values ranged from 16.97 to 36.43 with a median value of 22.59 (Interquartile range (IQR): 20.51-24.69), slightly higher among men (26.46±2.43) than among women (22.63±3.64, t=1.75, p=0.082). Men were taller (176.92±6.86 cm) than women (163.38±6.44 cm, t=12.77, p<0.001), and also heavier (73.76±10.55 vs. 60.5±10.81 kg, t=7.77, p<0.001, Table 1).

Digit ratios

Results regarding differences in the 2D:3D, 2D:4D and 4D:3D ratios for the right and the left hand are shown in Table 1. We can see that there are statistically significant differences in 4D:3D ratio of the right hand, that was greater among men (t=2.39, p=0.018). In the left hand, results of the 4D:3D ratio obtained for men and women were similar. The 2D:4D ratio in the left hand was greater among women (t=2.29, p=0.023) and also showed a nearly significant trend to higher values among the right hand of women (t=1.93, p=0.055). However, when this variable was compared using a non-parametric test (Mann-Whitney´s U-test), differences were highly significant (Z=3.08; p=0.002). In the right hand, a total of 11 women (10.89%) and 6 men (9.52%) showed a value of the 2D:4D ratio higher than 1 (i.e, longer index fingers than ring fingers). In the left hand, 8 women (7.89%) and 3 men (4.76%) showed longer index fingers than ring fingers. The 2D:3D digit ratio was significantly greater among women than among men (t=2.44, p=0.016) in the left hand, but not in the right one (t=0.12, NS). Considering only right-handed individuals (91 women and 58 men) differences in the left 2D:3D and 2D:4D indices still pre-

Table 1. Differences of several digit ratios among men and women in the study group (dorsal measurements).

	Women (n=101)	Men (n=63)	T; p
Left 4D:3D ratio	0.9413 ± 0.02107	0.9421 ± 0.02097	T=0.22; NS
Right 4D:3D ratio	0.9377 ± 0.03625	0.9471 ± 0.02138	T=2.39; p=0.018
Left 2D:4D ratio	0.9631 ± 0.02647	0.9535 ± 0.02507	T=2.29; p=0.023
Right 2D:4D ratio	0.9625 ± 0.02890	0.9535 ± 0.02958	T=1.93; p=0.055
Left 2D:3D ratio	0.9063 ± 0.02216	0.8980 ± 0.01931	T=2.44; p=0.016
Right 2D:3D ratio	0.9022 ± 0.01959	0.9026 ± 0.02174	T=0.12; NS
First phalanx/D4 length (right hand)	0.5676 ± 0.02023	0.5645 ± 0.02652	T=0.84; NS
First phalanx/D3 length (right hand)	0.5770 ± 0.01314	0.5780 ± 0.02241	T=0.37; NS
First phalanx/D2 length (right hand)	0.5906 ± 0.01893	0.5913 ± 0.03721	T=0.14; NS
First phalanx/D4 length (left hand)	0.5646 ± 0.01661	0.5618 ± 0.02869	T=0.78; NS
First phalanx/D3 length (left hand)	0.5782 ± 0.01807	0.5736 ± 0.02958	T=1.23; NS
First phalanx/D2 length (right hand)	0.5878 ± 0.01437	0.5856 ± 0.03594	T=0.56; NS
Weight (kg)	60.50 ± 10.81	73.76 ± 10.55	T=7.70; p<0.001
Heigth (cm)	163.38 ± 6.44	176.92 ± 6.86	T=12.77; p<0.001
Body mass Index (BMI; kg/m2)	22.63 ± 3.64	26.46 ± 2.43	T=1.76; NS

NS= non-significant

Table 2. Correlations among the total length of 2D, 3D and 4D fingers.

	Right Ring Finger	Right Middle Finger	Right Index Finger	Left Ring Finger	Left Middle Finger	Left Index Finger
Right Ring Finger		0.94***	0.92***	0.95***	0.94***	0.92***
Right Middle Finger	0.94***		0.95***	0.94**	0.97***	0.95***
Right Index Finger	0.92***	0.95***		0.92***	0.93***	0.96***
Left Ring Finger	0.95***	0.94***	0.92***		0.95***	0.93***
Left Middle Finger	0.94***	0.97***	0.93***	0.95***		0.95***
Left Index Finger	0.92***	0.95***	0.95***	0.93***	0.95***	

Women	Right Ring Finger	Right Middle Finger	Right Index Finger	Left Ring Finger	Left Middle Finger	Left Index Finger
Right Ring Finger		0.89***	0.87***	0.91***	0.88***	0.83***
Right Middle Finger	0.89***		0.91***	0.89**	0.93***	0.88***
Right Index Finger	0.87***	0.91***		0.86***	0.88***	0.93***
Left Ring Finger	0.91***	0.89***	0.86***		0.91**	0.87***
Left Middle Finger	0.88***	0.93***	0.88***	0.91***		0.89***
Left Index Finger	0.83***	0.88***	0.93***	0.87***	0.89***	

Men	Right Ring Finger	Right Middle Finger	Right Index Finger	Left Ring Finger	Left Middle Finger	Left Index Finger
Right Ring Finger		0.91***	0.84***	0.91***	0.89***	0.88***
Right Middle Finger	0.91***		0.89***	0.87**	0.92***	0.92***
Right Index Finger	0.84***	0.89***		0.78***	0.82***	0.91***
Left Ring Finger	0.91***	0.87***	0.78***		0.95***	0.93***
Left Middle Finger	0.89***	0.92***	0.82***	0.95***		0.96***
Left Index Finger	0.88***	0.92***	0.91***	0.93***	0.96***	

*** p<0.001

served their statistical significance (t=2.38, t=2.41, P<0.018 in both cases) and significant differences between men and women were also observed for the 4D:3D index in the right hand (t=2.31, p=0.022). When comparisons were made with the left hand no differences were observed, probably due to the small number of cases (only 10 women and 5 men).

We also tested whether there were differences in the first phalanx/ total finger length indices of the ring finger, the middle finger and the index finger among men and women. No differences were found (Table 1).

As expected all the indices showed direct correlation among themselves (Table 2), all in the total sample, among women only, and among men only. Similar results were observed when only the right-handed individuals were considered (data not shown).

If we compare the values of the 2D:3D, 2D:4D, and 4D:3D ratios among the left hand and the right hand we can see that there are no differences among them (Table 3).

Correlations with stature, BMI and age

We found a direct correlation between age and the 4D:3D index in the total sample (r=0.16, p=0.036) and an inverse correlation between height and the 2D:3D index of the left hand (r=-0.17, p=0.033); a multiple regression analysis showed that this relationship was dependent on sex. Indeed, when correlation analyses were performed separately among men and among women, no significant relationships were observed. Also, direct correlations were obtained between weight or BMI and the right 2D:3D ratio (rho=0.179 and rho=0.184; p=0.022 and p=0.018, respectively), but, again, multiple regression analyses showed that these relationships were dependent on sex.

Among women, we found a direct correlation between age and right 2D:3D (rho=0.22, p=0.018). We also found a relationship between the right 2D:3D ratio and BMI (rho=0.23, p=0.02). These relationships were not observed among men.

As expected, crude values of finger lengths were significantly related to stature (always with a p value <0.001; Table 4).

Table 3. Differences between the digit ratios among left hand and right hand in the total sample, women, and men separately.

	Left hand	Right hand	
WHOLE SAMPLE			
2D:4D ratio	0.9601 ± 0.02628	0.9591 ± 0.02941	T=0.35; NS
2D:3D ratio	0.9031 ± 0.02143	0.9023 ± 0.02420	T=0.35; NS
4D:3D ratio	0.9416 ± 0.02097	0.9413 ± 0.02486	T=0.14; NS
WOMEN			
2D:4D ratio	0.9598 ± 0.02558	0.9625 ± 0.02890	T=0.70; NS
2D:3D ratio	0.9063 ± 0.02216	0.9022 ± 0.01955	T=1.38; NS
4D:3D ratio	0.9413 ± 0.02107	0.9377 ± 0.02625	T=1.10; NS
MEN			
2D:4D ratio	0.9606 ± 0.02758	0.9535 ± 0.02958*	T=1.40; NS
2D:3D ratio	0.8980 ± 0.01931 ***	0.9024 ± 0.02190	T=1.19; NS
4D:3D ratio	0.9421 ± 0.02097	0.9471 ± 0.02138**	T=1.32; NS

*t=1.93; p=0.055 when men are compared with women.

**t=2.40; p=0.018 when men are compared with women.

*** t=2.44; p=0.016 when men are compared with women.

Table 4. Correlations between stature and finger lengths

	Right Ring Finger	Right Middle Finger	Right Index Finger	Left Ring Finger	Left Finger	Left Index Finger
WHOLE SAMPLE						
Stature	r=0.69***	r=0.69***	r=0.66***	r=0.68***	r=0.72***	r=0.68***
WOMEN						
Stature	r=0.42***	r=0.55***	r=0.51***	r=0.46***	r=0.59***	r=0.55***
MEN						
Stature	r=0.50***	r=0.55***	r=0.62***	r=0.50***	r=0.50***	r=0.48***

*** p<0.001

Multivariate analyses: discriminant functions

Using logistic regression analysis, introducing all of the calculated digit ratios, we found that the 2D:3D index of the left hand and the 4D:3D index of the right hand were independently related to sex. The introduction of the variable "stature" displaced the variables 2D:3D index of the left hand and the 4D:3D index of the right hand, but now the variable 2D:4D of the right hand was selected in second place as independently related to sex.

A discriminant function analysis showed that, including all the indices, the only ones that allow calculation of a discriminant function are the 2D:3D index of the left hand and the 4D:3D index of the right hand (y= 33.575 x left hand 2D:3D index- 28.40 x right 4D:3D index -3.586; centroid for women=0.21; centroid for men =-0.336). This function allows a correct classification of 59.4% of women and 61.9% of men, with an overall accuracy of 60.4%.

We applied this discriminant function to the test group (whose data are shown in Table 5), composed of 36 women and 24 men. It correctly classified 58.33% of the sample (50% of men and 63.8% of women).

If we introduce the crude values of finger lengths together with the indices the only selected variable is left D3 finger length, and the discriminant function y= 0.159 x left D3 finger length -16.660 allows a correct classification of 81.2% of women and 85.7% of men, with an overall accuracy of 82.9%.When this formula is applied to the test group, the proportion of correctly classified men increases to 91.66%, but that of correctly classified women decreases to 41.66%, with an overall accuracy of 65%.

If we introduce the variable stature, the discriminant function is y=-9.664 x 2D:4D of the right hand + 0.151 x stature -16.225. This function allows a correct classification of 85.1% of women and 87.3% of men, with an overall accuracy of 86%.

If we apply this discriminant function to the test group, overall accuracy was 81.67%, with a correct classification of 83.33% of women and 79.16% of

Table 5. Differences of several digit ratios among men and women in the test group (dorsal measurements).

	Women (n=36)	Men (n=24)	T; p
Left 4D:3D ratio	0.9462 ± 0.03214	0.9483± 0.02663	T=0.26; NS
Right 4D:3D ratio	0.9474 ± 0.02622	0.9506 ± 0.02058	T=0.51; NS
Left 2D:4D ratio	0.9713 ± 0.03513	0.9596 ± 0.03553	T=1.25; NS
Right 2D:4D ratio	0.9699 ± 0.0359	0.9575 ± 0.02622	T=1.51; NS
Left 2D:3D ratio	0.9181 ± 0.01446	0.9092 ± 0.01321	T=2.41; p=0.019
Right 2D:3D ratio	0.9184 ± 0.03111	0.9092 ± 0.01321	T=1.17; NS
First phalanx/D3 length (right hand)	0.5642 ± 0.03422	0.5609 ± 0.03108	T=0.38; NS
First phalanx/D2 length (right hand)	0.5646 ± 0.03791	0.5683 ± 0.02901	T=0.43; NS
First phalanx/D4 length (left hand)	0.5622 ± 0.03557	0.5726± 0.02160	T=1.29; NS
First phalanx/D3 length (left hand)	0.5692 ± 0.02953	0.5683 ± 0.02901	T=0.12; NS
First phalanx/D2 length (right hand)	0.5662 ± 0.03557	0.5681 ± 0.01694	T=0.32; NS
First phalanx/D3 length (right hand)	0.5630 ± 0.02538	0.5761 ± 0.02063	T=2.11; p=0.039
Weight (kg)	66.03 ± 13.19	84.04 ± 11.17	T=5.50; p<0.001
Heigth (cm)	163.53 ± 6.37	178.13 ± 8.06	T=7.82; p<0.001
Body mass Index (BMI; kg/m2)	22.63 ± 3.64	26.46 ± 2.43	T=1.62; NS

NS= non-significant

men.

DISCUSSION

The population group analysed was composed of young medical students. Although the series is relatively short, our results clearly show that men and women show different values of several digit indices, namely the 2D:4D ratios, both on the right and left hands, and also the left 2D:3D ratio and the right 3D:4D ratios. Statistical significance among men and women regarding these two last variables were higher than those observed for the 2D:4D ratio. In fact, multivariate analyses disclosed that sex was the independent variable that explained the relationships observed between several indices and stature or BMI in the whole study group. The relationship between the right 2D:3D ratio and BMI (rho=0.23, p=0.02) among women was not reproduced in the test group. Some other authors have also found relationships between digit ratios and BMI. Among men, Klimek et al. (2014) found an inverse relationship of BMI with the 2D:4D ratio. In contrast, Fink et al. (2006) found a positive, significant correlation between neck circumference (a surrogate marker of obesity) and the 2D:4D ratio, a result similar to what we observed among women with the 2D:3D digit ratio.

In the same sense the relationship observed between age and some indices has not been observed in large series (Xu and Zheng, 2015), neither was it observed in the test group in our study. We believe that it may obey to a type I statistical error rather than a true change in digit ratios when the oldest people are compared with the younger ones. In any case, this second possibility exists, and we have no solid argument to refute it. Manning et al. (2000) also report weak associations between the 2D:4D digit ratio and age for several ethnic groups, but they did not give an explanation for these findings. Conflicting results have been reported regarding the relationships of 2D:4D digit ratio and osteoarthritis –a disease of the aged- (Vehmas et al., 2006, who did not find any relation, *vs* de Kruijf et al. (2014), who did find an association). Recently, Kalichman et al. (2017) report a relationship between the 2D:4D ratio and an osseographic score related with skeletal aging. Indeed, osteoarthritic changes affecting fingers may profoundly alter finger measurements. In our series we have specifically excluded individuals with osteoarthritis, so we cannot provide any answer to this open question.

Several studies have assessed sexual dimorphism based on the 2D:4D ratios. Xi et al. (2014), in the Han ethnicity, found differences between men and women only in the right hand, absolute values being 0.95± 0.03 and 0.96± 0.03 (nearly identical as those reported in this study) respectively, by direct measurement of the basal crease of the finger proximal to the palm to the tip of the finger. Differences were even more marked when

Table 6. Compilation of some studies dealing with digit ratios. Authors listed in the first column are also included in the reference list.

Author	Country	Men		Women		Hand	Method
		n	2D:4D	n	2D:4D		
Evardone and Alexander (2009)	USA (Texas)	58	0.96 ± 0.03	52	0.97 ± 0.03	Right	Distance from the basal crease to the finger tip (ventral) (photocopies)
		58	0.96 ± 0.04	52	0.96 ± 0.04	Left	
Brown et al. (2002)	UK	28	0.9572 ± 0.0375	44	0.981 ±0.032	Right *	Distance from the basal crease to the finger tip (ventral) (photocopies)
		28	0.955 ± 0.079	44	0.968 ±0.005	Left	
Kumar et al.(I) (2017)	India	51	0.937 ±0.029	53	0.929 ±0.022	Right	Dorsal digit length calliper
		51	0.933±0.021	53	0.933±0.021	Left	
Kumar et al. (II)	India	86	0.935 ± 0.021	68	0.938 ±0.020	Right	Dorsal digit length calliper
			0.937±0.019		0.937±0.022	Left	
Vehmas et al. (2006)	Finland	---	------	490	0.925±0.021	Right	X-ray
Xi et al. (2014)	China (Han)	128	0.95 ± 0.03	122	0.96 ± 0.03	Right *	Distance from the basal crease to the finger tip (ventral)
		128	0.96 ± 0.03	122	0.97 ± 0.03	Left	
Xi et al. (2014)	China	128	0.92 ± 0.02	122	0.93 ±0.02	Right *	X-Ray classic
		128	0.92 ± 0.02	122	0.93 ±0.02	Left*	
Manning et al. (2000)	England	117	0.98 ±0.03	183	0.99 ±0.04	Right	Distance from the basal crease to the finger tip (ventral)
		117	0.98 ±0.04	183	0.99± 0.04	Left	
Manning et al. (2007)	Austria	169	0.979±0.041	135	0.990±0.042	Right	Self-reported Distance from the basal crease to the finger tip (ventral)
		169	0.988 ±0.041	135	0.991±0.039	Left	
	Belgium	644	0.981 ±0.044	428	0.989±0.047	Right	
		644	0.985 ±0.042	428	0.989±0.044	Left	
	Denmark	338	0.980±0.042	295	0.987±0.046	Right	
		338	0.987±0.042	295	0.990±0.048	Left	
	Finland	760	0.984±0.046	523	0.990±0.044	Right	
		760	0.986±0.044	523	0.990±0.041	Left	
	France	409	0.983±0.045	316	0.989±0.046	Right	
		409	0.986 ±0.044	316	0.986±0.045	Left	
	Germany	655	0.983 ±0.042	413	0.994±0.046	Right*	
		655	0.985 ±0.040	413	0.994±0.046	Left*	
	Ireland	2323	0.982±0.048	2260	0.991±0.050	Right*	
		2323	0.983±0.048	295	0.991±0.048	Left*	
	Netherlands	915	0.982±0.048	593	0.991±0.049	Right*	
		915	0.986±0.042	593	0.993±0.047	Left*	
	Norway	270	0.981±0.043	182	0.990±0.050	Right	
		270	0.983±0.042	182	0.989±0.047	Left	
	Sweden	670	0.982±0.050	291	0.995±0.051	Right	
		670	0.983 ±0.046	291	0.994±0.049	Left	
	Switzerland	255	0.983 ±0.041	165	0.990±0.042	Right*	
		255	0.983 ±0.040	165	0.989±0.037	Left*	
	U K	42602	0.985±0.047	33748	0.993±0.049	Right*	
		42602	0.986±0.047	33748	0.992±0.047	Left*	
	USA	20944	0.985±0.052	18692	0.998±0.055	Right*	
		20944	0.985±0.051	18692	0.995±0.053	Left*	

Author	Country	Men		Women		Hand	Method
		n	2D:4D	n	2D:4D		
Müller et al. (2017)	Germany	77	0.97± 0.03	140	0.98 ± 0.03	Right*	Distance from the basal crease to the finger tip (hand scan)
		77	0.97± 0.03	140	0.98 ± 0.03	Left	
Kaneoke et al. (2017)	Japan	----	------	403	0.963 ± 0.026	Right	Distance from the basal crease to the finger tip (hand scan)
				403	0.966 ± 0.026	Left	
Canan et al. (2017)	Turkey	283	0.991 ± 0.034	369	1.009 ± 0.038	Right*	Distance from the basal crease to the finger tip (Vernier calliper; direct)
		283	0.990 ± 0.035	369	0.997 ± 0.037	Left*	
Maitra et al. (2016)	Central India	500	0.967 ± 0.033	464	0.982 ± 0.027	Right*	Distance from the basal crease to the finger tip (Vernier calliper; direct)
		500	0.963 ± 0.037	464	0.974 ± 0.034	Left	
Neyse et al. (2016)	Germany	146	0.956 ± 0.028	139	0.967 ± 0.036	Right*	Distance from the basal crease to the finger tip (hand scan)
			0.961 ± 0.028		0.970 ± 0.034	Left *	
Kim et al. (2015)	Korea	257	0.947 ± 0.030	251	0.952 ± 0.037	Right	Distance from the basal crease to the finger tip (Vernier calliper; direct)
Masuya et al. (2015)	Japan	59	0.952 ± 0.026	57	0.953 ± 0.032	Right	Distance from the basal crease to the finger tip (ventral) (photocopies)
		59	0.950± 0.029	57	0.948± 0.033	Left	
Gorka et al. (2015)	USA (North Carolina)	211	0.959 ± 0.029	253	0.972 ± 0.034	Right *	Distance from the basal crease to the finger tip (ventral) (photocopies)
		211	0.950± 0.033	253	0.965± 0.034	Left *	
Xu and Zheng (2015)	Chinese (meta-analysis of 28 studies)	4488	0.948 (0.942-0.953)	4312	0.958 (0.952-0.964)	Right*	
		4220	0.951 (0.946-0.957)	3750	0.959 (0.953-0.965)	Left	
Apicella et al. (2016)	Hadza hunters (Tanzania)	76	0.989 ± 0.040	76	0.967 ± 0.040	Right	Distance from the basal crease to the finger tip (digital calliper; direct)
		76	0.984± 0.040	76	0.983± 0.040	Left	
Bosch-Domenech et al. (2014)	Spain	260	0.9597 ± 0.033	363	0.9717 ± 0.033	Right*	Distance from the basal crease to the finger tip (hand scan)
		260	0.9651 ± 0.032	363	0.9749 ± 0.032	Left*	

measurements were performed on X rays, either including or not soft tissue at the tip of the finger. Manning et al. (2007), also in Chinese population, found values of 0.974 among men and 0.986 among women on the right hand, and of 0.971 and 0.982, respectively, on the left hand. When these measurements were also obtained from a small British sample attending an infertility clinic, the results were 0.970 +/-0.04, or 0.960 +/-0.03, in both cases slightly higher than those observed here (Manning et al., 2004). In another English sample including 300 individuals, no differences among men and women were reported, with women showing 2D:4D ratios of 0.99 and men, of 0.98 (Manning et al, 2000). These measurements were obtained on the ventral aspect of hands. In the same manuscript data are provided for a Zulu population, which showed no differences among men and women, both sexes showing a 2D:4D ratio of 0.95; for Hungarian Gypsies, who also lack to show differences among sexes. Male Finns showed the lowest 2D:4D values (0.93), whereas Polish women, the highest ones (1.00). In Table 6 we compile some more studies dealing with digit ratios among different populations. Some of the data reported were obtained from very large series, such as those from China, USA and UK, although some of them are based on self-reported data. Overall, we can see, that, in general, men have shorter D2:D4 indices than women; right hand derived indices were more frequently statistically significantly different than left hand derived ones; however, in some geographical areas differences are not statistically significant. Our values, both for men and women, are slightly lower than the self-reported data derived from European and non-European countries, but they are indeed very similar to the data gathered using photocopies from white UK and USA individuals of both sexes, underscoring the importance of the method employed.

However, as in other studies, differences of digit ratios among sexes are relatively small, and this fact explains why the accuracy of a discriminant function based on the finger ratios is relatively low, as shown in this manuscript. A different question is the performance of discriminant functions that include crude values of finger length, because, in fact, finger length is a surrogate of stature, a variable that, within a given population, is highly dimorphic. This is clearly shown in the present study, in which inclusion of stature yields a discriminant function with more that 85% accuracy. Remarkably, this discriminant function also includes D2:D4 index, underscoring its value in assessing dimorphism. Although not an objective of the present study, if we briefly analyse the accuracy of other discriminant functions performed in order to estimate sex (based on tibial measurements, or mandibles, or teeth), we find that it ranges between 80-95% (Kranioti et al., 2017; Nathena et al., 2017; Gretwal et al., 2017). The introduction of new methods using standard databases that include measurements derived from thousands of individuals of known sex of several races and geographic areas allow a rapid estimation of sex of skeletal remains, something that can be complemented by molecular methods in cases in which remains are poorly preserved. This has been thoroughly reviewed recently (Krishan et al., 2016), but application of discriminant functions derived from foreign populations to a concrete case may yield non reliable results, as also pointed out in the mentioned review , and as we also reported some years ago (González-Reimers et al., 2015). Therefore, sex assignment of skeletal remains based on pure anthropometric data is still a difficult task, mainly due to differences in ethnicity. This limitation should be always considered when we try to estimate sex applying a discriminant function obtained from a different population.

In this study we provide evidence that the use of the classic digit ratios are by themselves of little aid in the discriminant analysis among sexes. However, when the crude finger length values are introduced the discriminate power markedly increases, and when stature is also included, the combination of stature and the D2:D4 digit ratio even increases the discriminant power. Crude values of finger length may better discriminate among sexes than digit ratios do, but they may also yield misleading results. Small hands with short fingers are probably more uncommon among men than are long fine fingers among women. Perhaps this explains why the discriminant function obtained with D3 length showed a greater accuracy when applied to men in the test group, but a lower one when applied to women.

As expected, there were significant correlations between finger length and stature, but not between most of the digit ratios and stature. Stature, in most modern populations, is a highly dimorphic variable, but this assertion is not of universal validity, and differences in stature vary among countries and ethnicity. Interestingly, in our study the 2D:4D digit ratio of the right hand shows an independent discriminant power, even when stature is also included in the analysis. The validity of this result is confirmed when this function (including stature and D2:D4 digit ratio) was applied to the test group, yielding accuracy values similar to those observed in the study group.

Therefore, we conclude that among the modern population of Tenerife, in the Canary Islands, the 2D:4D digit ratios of both hands, the left 2D:3D ratio, and the 4D:3D of the right hand are different among men and women, always smaller among men than among women. The magnitude of the difference among sexes is similar to that reported for other populations, and it allows for the elaboration of a discriminant function with an accuracy of 60.4%, that reaches 86% if stature is also included.

REFERENCES

APICELLA CL, TOBOLSKY VA, MARLOWE FW, MILLER KW (2016) Hadza hunter-gatherer men do not have more masculine digit ratios (2D:4D). *Am J Phys Anthropol,* 159: 223-232.

BROWN WM, HINES M, FANE BA, BREEDLOVE SM (2002) Masculinized finger length patterns in human males and females with congenital adrenal hyperplasia. *Horm Behav,* 42: 380-386.

CANAN F, KARACA S, DÜZGÜN M, ERDEM AM, KARAÇAYLI E, TOPAN NB, LEE SK, ZHAI ZW, KULOĞLU M, POTENZA MN (2017) The relationship between second-to-fourth digit (2D:4D) ratios and problematic and pathological Internet use among Turkish university students. *J Behav Addict*, 6: 30-41.

ECKER A **(***1875***)** Einige Bemerkungen über ein schwankenden Charakter in der Hand des Menschen. *Archiv für Anthropol,* 8: 68-74.

EVARDONE M, ALEXANDER GM (2009) Anxiety, sex-linked behaviors, and digit ratios (2D:4D). *Arch Sex Behav,* 38: 442-455.

FERRARO B, WILDER FV, LEAVERTON PE (2010) Site specific osteoarthritis and the index to ring finger length ratio. *Osteoarthritis Cartilage,* 18: 354-357.

FINK B, MANNING JT, NEAVE N (2006) The 2nd-4th digit ratio (2D:4D) and neck circumference: implications for risk factors in coronary heart disease. *Int J Obes (Lond),* 30: 711-714.

GONZÁLEZ-REIMERS E, TRUJILLO-MEDEROS A, ORDÓÑEZ AC, CASTAÑEYRA-RUIZ M, ARNAY-DE-LA-ROSA M (2015) Sexual dimorphism: A comparative study between the prehispanic inhabitants from El Hierro and other populations of the world. *Eur J Anat,* 19: 57-64.

GORKA AX, NORMAN RE, RADTKE SR, CARRÉ JM, HARIRI AR (2015) Anterior cingulate cortex gray matter volume mediates an association between 2D:4D ratio and trait aggression in women but not men. *Psychoneuroendocrinol,* 6: 148-156.

GREWAL DS, KHANGURA RK, SIRCAR K, TYAGI KK, KAUR G, DAVID S (2017) Morphometric analysis of odontometric parameters for gender determination. *J*

Clin Diagn Res, 11: ZC09-ZC13.

HAMPSON E, SANKAR S (2012) Re-examining the Manning hypothesis: androgen receptor polymorphism and the 2D:4D digit ratio. *Evol Hum Behav,* 33: 557-561.

ISCAN MY, MILLER-SHAIVITZ P (1984) Determination of sex from the tibia. *Am J Phys Anthropol,* 64: 53-57.

JEEVANANDAM S, MUTHU PK (2016) 2D:4D Ratio and its implications in medicine. *J Clin Diagn Res,* 10: CM01-CM03.

KALICHMAN L, BATSEVICH V, KOBYLIANSKY E (2017) 2D:4D finger length ratio and skeletal biomarker of biological aging. *Anthropol Anz,* 74: 221-227.

KANEOKE Y, DONISHI T, IWAHARA A, SHIMOKAWA T (2017) Severity of premenstrual symptoms predicted by second to fourth digit ratio. *Front Med (Lausanne)*, 4: 144.

KIM TB, OH JK, KIM KT, YOON SJ, KIM SW (2015) Does the mother or father determine the offspring sex ratio? Investigating the relationship between maternal digit ratio and offspring sex ratio. *PLoS One,* 10: e0143054. doi: 10.1371/journal.pone.0143054.

KLIMEK M, GALBARCZYK A, NENKO I, ALVARADO LC, JASIENSKA G (2014) Digit ratio (2D:4D) as an indicator of body size, testosterone concentration and number of children in human males. *Ann Hum Biol,* 41: 518-523.

KONDO T, ZÁKÁNY J, INNIS JW, DUBOULE D (1997) Of fingers, toes and penises. *Nature,* 390: 29.

KRANIOTI EK, GARCÍA-DONAS JG, ALMEIDA PRADO PS, KYRIAKOU XP, LANGSTAFF HC (2017) Sexual dimorphism of the tibia in contemporary Greek-Cypriots and Cretans: Forensic applications. *Forensic Sci Int*, 271: 129. e1-129.e7. doi: 10.1016/ j.forsciint.2016.11.018.

KRISHAN K, CHATTERJEE PM, KANCHAN T, KAUR S, BARYAH N, SINGH RK (2016) A review of sex estimation techniques during examination of skeletal remains in forensic anthropology casework. *Forensic Sci Int,* 261: 165. e1-8. doi: 10.1016/ j.forsciint.2016.02.007.

DE KRUIJF M, KERKHOF HJ, PETERS MJ, BIERMA-ZEINSTRA S, HOFMAN A, UITTERLINDEN AG, HUGGEN FJ, VAN MEURS JB (2014) Finger length pattern as a biomarker for osteoarthritis and chronic joint pain: a population-based study and meta-analysis after systematic review. *Arthritis Care Res (Hoboken),* 66: 1337-1343.

KUMAR S, VORACEK M, SINGH M (2017) Sexual dimorphism in digit ratios derived from dorsal digit length among adults and children. *Front Endocrinol (Lausanne),* 8: 41.

LUTCHMAYA S, BARON-COHEN S, RAGGATT P, KNICKMEYER R, MANNING JT (2004) 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Hum Dev*, 77: 23-28.

MANNING JT, BUNDRED PE (2000) The ratio of 2nd to 4th digit length: a new predictor of disease predisposition? *Med Hypotheses*, 54: 855-857.

MANNING JT, FINK B (2008) Digit ratio (2D:4D), dominance, reproductive success, asymmetry, and sociosexuality in the BBC Internet Study. *Am J Hum Biol,* 20: 451-461.

MANNING JT, SCUTT D, WILSON J, LEWIS-JONES DI (1998) The ratio of 2nd to 4th digit length: a predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Hum Reprod*, 13: 3000-3004.

MANNING JT, BARLEY L, WALTON J, LEWIS-JONES DI, TRIVERS RL, SINGH D, THORNHILL R, ROHDE P, BERECZKEI T, HENZI P, SOLER M, SZWED A (2000) The 2nd:4th digit ratio, sexual dimorphism, population differences, and reproductive success. Evidence for sexually antagonistic genes? *Evol Hum Behav,* 21: 163-183.

MANNING JT, WOOD S, VANG E, WALTON J, BUNDRED PE, VAN HEYNINGEN C, LEWIS-JONES DI (2004) Second to fourth digit ratio (2D:4D) and testosterone in men. *Asian J Androl*, 6: 211-215.

MANNING JT, CHURCHILL AJ, PETERS M (2007) The effects of sex, ethnicity, and sexual orientation on self-measured digit ratio (2D:4D). *Arch Sex Behav*, 36: 223 -233.

MANNING JT, FINK B, NEAVE N, CASWELL N (2016) Photocopies yield lower digit ratios (2D:4D) than direct finger measurements. *Early Hum Dev*, 100: 21-25.

MAITRA A, MAITRA C, JHA DK, BISWAS R (2016) Finger length ratio (2D:4D) in central India and an attempt to verify fraternal birth order effect: a population based cross-sectional study. *J Clin Diagn Res,* 10: CC09-CC12.

MASUYA Y, OKAMOTO Y, INOHARA K, MATSUMURA Y, FUJIOKA T, WADA Y, KOSAKA H (2015) Sex-different abnormalities in the right second to fourth digit ratio in Japanese individuals with autism spectrum disorders. *Mol Autism,* 6: 34.

MÜLLER M, BRAND M, MIES J, LACHMANN B, SARIYSKA RY, MONTAG C (2017) The 2D:4D marker and different forms of internet use disorder. *Front Psychiatry*, 8: 213.

NATHENA D, MICHOPOULOU E, KRANIOTI EF (2017) Sexual dimorphism of the calcaneus in contemporary Cretans. *Forensic Sci Int,* 277: 260. e1-260.e8. doi: 10.1016/j.forsciint.2017.04.005.

NEYSE L, BOSWORTH S, RING P, SCHMIDT U (2016) Overconfidence, incentives and digit ratio. *Sci Rep,* 6: 23294. doi: 10.1038/srep23294.

PHELPS VR (1952) Relative index finger length as a sex-influenced trait in man. *Am J Hum Genet*, 4: 72-89.

RIBEIRO E(JR), NEAVE N, MORAIS RN, KILDUFF L, TAYLOR SR, BUTOVSKAYA M, FINK B, MANNING JT (2005) Digit ratio (2D:4D), testosterone, cortisol, aggression, personality and hand-grip strength: Evidence for prenatal effects on strength. *Arch Sex Behav*, 34: 329-333.

ROBINSON SJ, MANNING JT (2000) The ratio of 2nd to 4th digit length and male homosexuality. *Evol Hum Behav,* 21: 333-345.

TOMKINSON JM, TOMKINSON GR (2017) Digit ratio

(2D:4D) and muscular strength in adolescent boys. *Early Hum Dev*, 113: 7-9.

VEHMAS T, SOLOVIEVA S, LEINO-ARJAS P (2006) Radiographic 2D:4D index in females: no relation to anthropometric, behavioural, nutritional, health-related, occupational or fertility variables. *J Negat Results Biomed,* 5: 12.

XI H, LI M, FAN Y, ZHAO L (2014) A comparison of measurement methods and sexual dimorphism for digit ratio (2D:4D) in Han ethnicity. *Arch Sex Behav,* 43: 329-333.

XU Y, ZHENG Y (2015) The digit ratio (2D:4D) in China: A meta-analysis. *Am J Hum Biol*, 27: 304-309.