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Relationships between Sociosexuality and Dermatoglyphic Traits

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Abstract: In humans, prenatal development of brain dispositions to sex differences in mating behavior is difficult to study directly. Indirect prenatal markers, including dermatoglyphics, present a viable option.

In this study we tested a hypothesis that some radio-ulnar contrasts in dermatoglyphic ridge counts could be related with human sociosexuality.

Sociosexual Orientation Inventory (SOI) data from 180 young adults, along with fingerprints of their terminal phalanges (via hand scanning) were collected, and relationships between SOI and dermatoglyphics were analyzed.

Typical sex differences in SOI were recorded with higher scores in males and lower in females. Among other results we found that on the index finger lower number of triradii and cores (i.e., mostly in loop type dermatoglyphic patterns) and radial-biased within-finger asymmetry in ridge counts typical for ulnar loops were connected with typical sex differences in SOI (higher in males and lower in females) while in subjects possessing an opposite dermatoglyphic arrangement – higher numbers of cores and triradii and ulnar-biased within-finger ridge count asymmetry typical in radial loops – sex differences in SOI scores disappeared. Recognized significant and systematic trends were mostly connected with variables derived from dermatoglyphic features on the 2nd and 4th fingers.

Possible relationships with prenatal androgen causation are discussed.

Key words: radio-ulnar asymmetry, sex development, prenatal programming, sexual behavior, sex differences

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Introduction

Sociosexuality and its prenatal dispositions

Sociosexuality has been defined as a variable willingness to have sex outside the committed pair bond (Simpson and Gangestad 1991). Largely applied self-report sociosexual inventories (Simpson and Gangestad 1991; Penke and Asendorpf 2008) contained several items reflecting actually performed sociosexual *behavior* (number of sexual partners, one-night sex occasions), as well as sexual *desire* (internal forces of sex drive and preferences, regardless if realized or not) and *attitudes* to this aspect of sexuality (mostly learned and also culturally forced, but not necessarily without innate influences). Therefore, sociosexuality in a way reflects a complex issue of trade-off between quality and quantity of sexual relations (sexual/reproductive evolutionary strategies) of each subject which is essential from evolutionary (life-history) point of view because it can make reproductive differentials between subjects representing different levels of sociosexuality.

Across human populations, sex differences in sociosexuality are influenced both by biological and social factors (Lippa 2007; 2009). While social factors of sociosexuality are relatively easy to study via questionnaires in surveys, the innate part of variation in sociosexuality is more difficult to investigate even though it is also important (Bailey et al. 2000; Lyons et al. 2004), i.e., the variation people are predisposed to from prenatal development by their genes and/or prenatal programming, which can, genetically or epigenetically, be passed on to the following generations.

Predispositions to sexual behavior in general are developed in the human brain prenatally under an influence of prenatal sex differentiation factors, especially the expression of genes from sex chromosomes locally in each cell (Arnold 2014 for review) in a combination with sex hormones produced centrally by prenatal gonads and secreted to the embryonal/fetal circulation (Cohen-Bendahan et al. 2005 for review), see e.g., Mitsui et al. (2016; 2019) for recent examples. In North American adult men and women, sociosexuality – defined as comparison between monoamorously vs. polyamorously behaved subjects – was related to levels of testosterone (van Anders et al. 2007), even though the relationship between sociosexuality and testosterone might not be so straightforward when long term changes during the partnerships are taken into account (Puts et al. 2015). It is unclear, however, how levels of prenatal testosterone are involved in the predispositions for adult sociosexuality. Results of testing relationships between 2D:4D ratio – as a putative marker of prenatal testosterone – with sexually dimorphic behavioral traits were not unequivocal (Charles and Alexander 2011; DeLecce et al. 2014; Wong and Hines 2016).

Sex differences in dermatoglyphics and relationships to behavior

There are some indications that dermatoglyphics, initiating its development in 10th to 11th weeks *in utero* (Loesch 1983:18–24; Babler 1991), could be used as a potential indirect marker of prenatal sexual differentiation and its prenatal influence on brain predispositions of human behaviour (Bracha et al. 1991; Fatjó-Vilas et al. 2008; Golembo-Smith et al. 2012), including sexual behavior and sociosexuality. The primary argument for such associations is a strong, prenatally fixed sexual dimorphism of

many dermatoglyphic traits (Schwidetzky and Jantz 1979; Králík et al. 2019).

Among other sex relationships, in the majority of human samples, genetically normal males have on average higher Total Finger Ridge Count (TFRC) and higher hand asymmetry in the ridge count than genetically normal females of the same population (Kunter and Rühl 1995). Strong negative relationship between TFRC and number (dose) of sex chromosomes has been found; the higher number of sex chromosomes in a genome, the lower TFRC (Penrose 1963; Alter 1965; Penrose 1967; Jantz and Hunt 1986). However, it is not clear whether the origin of this dimorphism is due directly to genetic differences in each cell or is mediated by prenatal differences in the action of steroid sex hormones. Nor do the results of studies of people with normal karyotypes (male 46,XY, female 46,XX) and disorders of sexual development, including congenital adrenal hyperplasia (Qazi and Thompson 1971; Börger et al. 1986), or steroid receptor disorders such as testicular feminization syndrome (Polani and Polani 1979), offer a clearer view. At present, therefore, it is not possible to say unequivocally whether the sex differences in dermatoglyphic traits is purely genetic in origin or caused by prenatal differences in sex steroid hormone levels, or some other mechanism mentioned by Arnold (2014), or a combination of different mechanisms. In any case, however, associations have been found between sexual dimorphism of dermatoglyphic traits and certain types of sexually dimorphic behavior.

Some studies tried to find direct relationships between dermatoglyphics and a "sexually typical behavior" that can be predisposed by a prenatal setting, in particular, if dermatoglyphic features or values non-typical for a given sex are found in subjects with a sexually non-typical behavior (Cohen-Bendahan et al. 2005). There are no clear empirical results for relationship between prenatal testosterone levels and right/left *side asymmetry* in dermatoglyphic features and prenatal testosterone. Females have usually more symmetrical patterns than males. In homosexual males (Hall and Kimura 1994) more symmetrical or even leftward asymmetrical (i.e., more feminine) ridge counts were found but another independent study (Mustanski et al. 2002) did not confirm the result and neither did the study of homosexual transsexuals (Slabbekoorn et al. 2000). Another study of transsexuals (Green and Young 2000) found higher frequency of leftward asymmetry in male homosexual transsexuals than in control heterosexual males and heterosexual transsexuals which is in congruence with the expectation, but they reported no differences between male and female controls in directional asymmetry in the ridge count which is not in congruence with the expectation. In female monozygotic twin pairs discordant in sexual orientation (Hall 2000), lower (i.e., more feminine) ridge count was found in lesbians than in their heterosexual twins which is, however, *not* in congruence with supposed role of testosterone in sexual orientation. Additionally, females with leftward ridge count bilateral asymmetry (more typical for females than males) reached better results in language cognitive tasks (perception, fluency), while females with rightward ridge count asymmetry (more typical for males than females) were better in space orientation and mathematical skills that are usually on average better handled by males (Kimura and Carson 1995; Kimura and Clarke 2001).

To sum up, some relationships between dermatoglyphic variations and sex development have been found (Schwidetzky and Jantz 1977; 1979; Králík et al. 2019), however, empirical evidence linking dermatoglyphics to sexuality other than sexual identity and sexual orientation is scarce. One cause might be an inappropriate methodological nature of dermatoglyphic variables used. So far distinguished, defined and studied dermatoglyphic features (ridge count, right/left directional asymmetry) might not be sufficiently sensitive to hormonal action *in utero*. On the contrary, *within-individual* gradients in dermatoglyphic features (e.g., between fingers) might be crucial for studies of prenatal factors, analogically to the 2D:4D ratio (Manning 2002). According to one piece of supporting evidence (Králík et al. 2019b), sex differences in proportions of dermatoglyphic whorl patterns increases significantly *from radial to ulnar fingers*, i.e., from the thumb to the little finger. It indicates that sexes differ in dermatoglyphic development mostly in the ulnar side of the hand. Although not abundantly studied, radioulnar variations might be sensitive both to internal (genetic) and external (environmental) disturbances of developmental processes. Radio-ulnar asymmetry within fingers reflects the number of sex chromosomes in the karyotype (Jantz and Hunt 1986) and differences between radial and ulnar fingers, e.g., differences between ridge counts on the 1st and the 5th finger, are sensitive to seasonal variations during dermatoglyphic development (Kahn et al. 2001; 2008; 2009).

Recent studies (Polcerová et al. 2022a; 2022b; Polcerová et al. 2023) have found that several radioulnar contrasts (numerically: differences between two ridge counts) on the right hand, involving the radial ridge count on the 2nd finger, were dimorphic in the same sense in all 21 study populations examined. This may indicate that these contrasts are targeted by prenatal sex differentiation factors common to all human populations and could therefore be used as prenatal markers of sexual differentiation, as the 2D:4D ratio is used.

Aims of the study

To our present knowledge, there are no studies on the relationship between dermatoglyphics and sociosexuality. The aim of the study was to describe (innate) sex differences in dermatoglyphic radioulnar patterns on fingers and to find out whether human sociosexuality, as measured by sociosexual orientation inventory (SOI), is related to dermatoglyphics as putative markers of prenatal sexual development. Based on previous studies we hypothesize that radio-ulnar contrasts in dermatoglyphic features will be related to variations in sociosexuality.

Materials and methods

Studied subjects

The studied sample represents 180 young adult people (mean age 23.3 years, range from 18 to 35 years), 87 females (mean age 23.9 years) and 93 males (mean age 22.7 years). The subjects were mostly recruited from students of secondary schools and universities in Brno, Czech Republic. The data were collected within the frame of a project which was approved in advance by the Ethical Committee for Research of our university (protocols: EKV-2017-052 and another one with approval letter) and all subjects signed informed consent with their participation in the study. A preliminary version of this analysis was part of the first author's (P.I.) defended dissertation.

Sociosexual Orientation Inventory

Sociosexuality was recorded using local language version of seven-items Sociosexual Orientation Inventory – SOI (Simpson and Gangestad 1991). The inventory is a self-reporting questionnaire composed of seven items. The first three items (1–3) reflect real or perceived sociosexual behavior (number of sex partners over the last 12 months, number of supposed sex partners in the future 5 years, and number of "one-night stands" ever) and the answers are open. Item 4 (frequency of imagination having sex with someone else than the current partner) intended to reflect a hidden sociosexual desire and it is rated on an 8-point ascending heterogeneous scale, from 1 (never) to 8 (at least once a day). Items 5–7 reflect sociosexual attitudes towards casual sex (of the respondent-self and other people/in general; all three are similar but item 7 is formulated with reverse meaning from the remaining two items) and are rated on a 9-point Likert scale from 1 (strongly disagree) to 9 (strongly agree). From the answers to these 7 items, the sociosexuality score (SOI) is calculated according to the formula SOI = (5 × item 1) + (1 × item 2) + (5 × item 3) + (4 × item 4) + [2 × (aggregate of items 5, 6 and reverse values of item 7)]. Despite fact that the final SOI score represents discrete values the scale usually represents relatively wide range of values from a methodologically given lower border to a variable upper tail. Technical Note: In the original publication of SOI method (Simpson and Gangestad 1991) the principle of combination of the last three items of the inventory is described by the term "aggregate". In our opinion, this means "sum", in fact. However, in many studies after the original one, other authors used a procedure of averaging (in fact the arithmetic mean). This is probably true also for the comparative study of many human populations by Schmitt (2005) which involves the only available comparative data on SOI for Czech and Slovak populations known to us. This was the reason we also computed the combination of the last component (attitudes) of the SOI scores as the mean and not a sum.

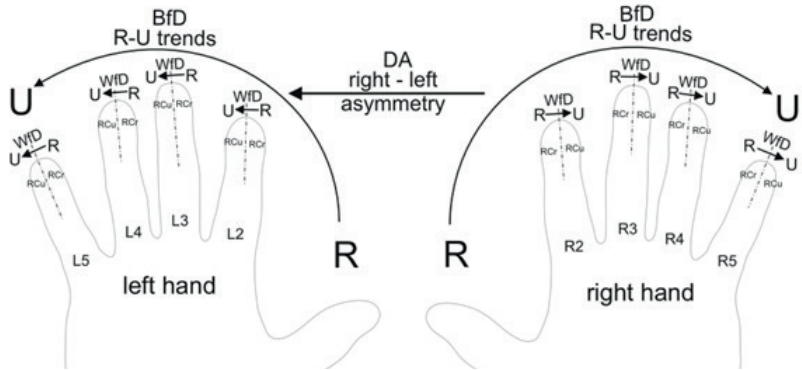

Fig. 1. Studied variables. Schematic illustration of studied positions and ridge-count variables on the human hands: right (R2 – R5) and left (L2 – L5) hand fingers, RCr (radial ridge count) and RCu (ulnar ridge count) on each finger, WfD (within-finger difference) on each finger, BfDs (between finger differences from 2 minus 3 to 4 minus 5) on each hand, and DA (directional asymmetry, right minus left) for RCr and RCu on each finger. The diagram of the hands corresponds to the position of how the handprints look when both hands are printed on paper at the same time in the traditional way, or how we see our own hands from the dorsal side when we scan them on a desktop scanner

Dermatoglyphics

The human hands were scanned by means of 2D flatbed scanner (one type for the whole sample) into color TIFF images using a method adopted for published studies (Králík et al. 2014; 2019a). Since thumbs were recorded from the radial side on scans and their ulnar sides were mostly not available, we studied dermatoglyphic variations in the four fingers only (2nd to 5th finger).

We applied standard dermatoglyphic methodology (Cummins and Midlo 1961) as implemented in open source software *Dermatoglyphix* (Králík et al. 2017). On fingers, all dermatoglyphic points (cores and triradii) were identified according to the methodology standardized by Cummins and Midlo (1961) and subsequent variables for each fingerprint were recorded (see Figure 1 for ridge-count variables).

Number of triradii (nT)

Number of triradii representing in raw form a counting variable ranging from 0 to 2 (Supplementary materials Table S1) were analyzed in the form of two categories (nT): 1 – patterns with 1 or no triradius, 2 – patterns with 2 or more triradii. In the sense of traditional pattern classification, category 1 represents loops, tented arches and arches, i.e., less complicated configurations of ridges, while category 2 represents all whorls and composites (eventually complicated accidentals), i.e., more complex patterns.

Number of cores (nC)

Number of cores representing in raw form a counting variable ranging from 0 to 2 were analyzed in the form of two categories (nC): 1 – patterns with 1 or no core, 2 – patterns with 2 or more cores. In the sense of traditional pattern classification, category 1 represents no-core or simple core patterns (arches, tented arches, loops, simple whorls and central pockets), while category 2 represents double whorl patters (lateral pockets and twin-loops, eventually complicated accidentals with more cores). The variable hence represents a measure of complexity in the center of the pattern.

Radial ridge count (RCr)

Radial ridge count (RCr) was recorded as counted variable: count of ridges between the radial triradius and core, if both present. If a pattern had no core or triradius RCr was zero (0), if number of cores was higher than 1, the radial core (closer to radial triradius) was taken. When counting ridges, endpoints (point of core and point of triradius) were not counted following methodology by Holt (1951; 1961; 1979).

Ulnar ridge count (RCu)

Ulnar ridge count (RCu) was recorded as counted variable: count of ridges between the ulnar triradius and core, if both present. If a pattern had no core or triradius RCu was zero (0), if number of cores was higher than 1, the ulnar core (closer to ulnar triradius) was taken. For this and other ridge counts applied that when counting ridges, endpoints (point of core and point of triradius) were not counted.

Radio-ulnar difference within fingers (WfD)

Radio-ulnar difference of ridge counts within each fingerprint (WfD) was established as a difference between radial (RCr) and ulnar (RCu) ridge count (radial minus ulnar) on each finger. For both hands eight variables were computed, from L2.WfD for the left 2nd finger to

R5.WfD for the right 5th finger similarly to the approach applied in Polcerová et al. (2022a).

Radio-ulnar difference between fingers (BfD)

Radio-ulnar difference in ridge counts between fingers (BfD) was computed as a difference between ridge counts on a radial and an ulnar (radial minus ulnar) finger. In each body side (hand), this was computed for each type of ridge count (RCr, RCu) and each pair of fingers (BfDr, BfDu).

Directional asymmetry between respective fingers

Body side asymmetry (DA) was computed as right-left difference (right minus left) in each type of ridge count (DAr for RCr, DAu for RCu) between respective fingers on right and left hand.

Statistical procedures

All computations with data and statistical methods were performed in the *R software* (R Core Team 2019). Descriptive statistics were computed for each recorded variable. Sex differences in frequencies of triradii (nT) and cores (nC) were tested by means of Pearson's Chi-squared test with Yates' continuity correction. Sex differences in ridge counts (including derived variables) and SOI scores were assessed by means of two sample permutation test (with 100,000 permutes) in the R-package *EnvStats* (Millard 2013). The significance of directional asymmetry was tested by means of one sample permutation test (with 100,000 permutes) of mean DA value against zero (0).

Dermatoglyphic variables were used as independent variables (categorical or continuous factors) and SOI scores as dependent variables (effects) and we tested how SOI scores change in relation to dermatoglyphic variables. To test the effects of categorial variables (nT, nC) on SOI scores we applied two-way nonparametric analysis of variance (so called "robust analysis of variance", RAOV) was applied where obligate Euclidean distance (usual in parametric ANOVA) is replaced by a distance called Jaeckel's (1972) dispersion function based on a rank estimation (Hocking 2003; Hettmansperger and McKean 2011). This method is available for practical usage in the R-package *Rfit* (Kloke and McKean 2012).

For statistical assessment of effect of ridge counts (RCr, RCu), and variables derived from them (WfD, BfD, DA) to SOI we used the same statistical approach. Values of each ridge count variable were divided into two categories (lower, higher) with approximately same sample sizes and the effect of the categories (along sex category and interaction term) was tested by means of the RAOV. In visualization plots, mean values were estimated as Huber M-estimator with Wald-type confidence intervals and they were computed in R-package *rcompanion* (Mangiafico 2015).

Results

Sociosexuality Orientation Inventory

Mean SOI score values were 29.3 (SD = 17.8, N = 69) and 46.3 (SD = 23.8, N = 62) for females and males, respectively. The sex difference was highly statistically significant (two sample permutation test: p-value = 0). Distribution of the values of the SOI scores was not normal in either males or females. For all subsequent tests we used SOI transformed into a form of its natural logarithm (logSOI).

Table 1. Frequencies of nT and nC for each finger and sex separately. Legend: ratio – ratio between count of category 2 and 1 reflecting a proportion of more complex patterns, Chi.sq. – value of Chi-square statistics (degrees of freedom were always equal to 1), p-value – significance of the Chi-square test of the proportion between the frequencies in males and females (two sided hypotheses)

Finger	nT								nC							
	Males			Females			Chi-sq.	p-value	Males			Females			Chi-sq.	p-value
	1	2	ratio	1	2	ratio			1	2	ratio	1	2	ratio		
L2	47	15	0.32	44	22	0.50	0.893	0.34	56	6	0.11	58	8	0.14	0.025	0.87
L3	47	15	0.32	58	11	0.19	0.927	0.34	52	10	0.19	61	8	0.13	0.249	0.62
L4	44	18	0.41	47	21	0.45	0.001	0.97	59	3	0.05	61	7	0.11	0.700	0.40
L5	55	7	0.13	59	8	0.14	0.000	1.00	59	3	0.05	64	3	0.05	0.000	1.00
R2	41	20	0.49	46	20	0.43	0.012	0.91	56	5	0.09	59	7	0.12	0.026	0.87
R3	50	12	0.24	58	10	0.17	0.223	0.64	58	4	0.07	65	3	0.05	0.016	0.90
R4	30	32	1.07	37	31	0.84	0.261	0.61	59	3	0.05	64	4	0.06	0.000	1.00
R5	46	15	0.33	58	8	0.14	2.536	0.11	55	6	0.11	65	1	0.02	2.768	*0.10*

Descriptive statistics and sex differences

Frequencies of nT and nC are available in the Table 1, including results of tests for differences between frequencies in males and females. Sexes did not statistically differ in frequencies of nT and nC (except of borderline significance in nC of R5), however values of ratio between number of cases with complicated patterns (nT=2) and more simple patterns (nT=1) were always higher in males than in females in each right-hand finger (but not in the left-hand fingers). This was not found for nC.

Table 2. Descriptive statistics and sex differences in ridge counts. Descriptive parameters and tests of sex differences of ridge count variables (RCr, RCu) and within-finger ridge count differences (WfD) for each finger and sex separately; N – number of cases, Mean – arithmetic mean, SD – standard deviation, Min – minimum, Max – maximum, Med – median, Q05 – 5% quantile, Q95 – 95% quantile each finger and sex separately; ratio – ratio between count of category 2 and 1 reflecting a proportion of more complex patterns, Chi.sq. – value of Chi-square statistics (degrees of freedom were always equal to 1), p-value – significance of the Chi-square test of the proportion between the frequencies in males and females (two sided hypotheses)

Finger	Females								Males								Sex Diff	p-value
	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95		
RCr																		
L2	91	7.16	6.56	0	20	6	0	18.5	91	8.31	7.28	0	22	8	0	19	1.14	0.27
L3	81	10.62	6.87	0	24	13	0	20	89	12.22	5.82	0	24	13	0	20	1.61	0.10
L4	62	13.35	7.35	0	27	14	0	24	84	15.89	5.79	0	27	17	4	24	2.54	**0.02**
L5	71	11.59	5.87	0	22	12	2.5	20.5	78	13.35	4.83	0	24	14	5.85	21.2	1.75	**0.05**

	Females								Males								
Finger	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95	Sex Diff	p-value
RCr																		
R2	99	7.25	6.37	0	20	8	0	18	92	5.92	6.56	0	21	3	0	17.5	-1.33	0.16
R3	92	11.54	5.87	0	24	12	0	20.5	90	11.40	6.60	0	24	13	0	20.6	-0.14	0.88
R4	69	14.39	7.00	0	26	16	0	23	80	15.36	6.04	0	25	17.5	2	23	0.97	0.37
R5	73	12.41	5.58	1	23	13	3.6	20.4	79	13.11	4.43	3	22	14	6	20.1	0.70	0.39
RCu																		
L2	91	6.29	7.91	0	26	2	0	21	91	6.78	8.33	0	30	2	0	21	0.49	0.69
L3	81	2.48	5.91	0	27	0	0	17	89	2.51	5.66	0	23	0	0	15.6	0.02	0.98
L4	62	4.02	6.57	0	22	0	0	17.9	83	3.47	5.86	0	22	0	0	16.9	-0.55	0.61
L5	70	0.76	2.62	0	13	0	0	6.2	78	0.63	2.34	0	13	0	0	5.45	-0.13	0.77
R2	99	5.83	8.27	0	25	0	0	21	92	8.78	8.64	0	25	8	0	23.5	2.95	**0.02**
R3	92	2.10	6.03	0	27	0	0	18.5	60	2.40	5.98	0	23	0	0	18.6	0.30	0.74
R4	69	4.43	6.44	0	24	0	0	16.6	80	6.04	0.00	0	24	1	0	17.1	1.60	0.15
R5	72	0.86	2.83	0	15	0	0	8.45	79	1.89	4.20	0	16	0	0	12	1.02	*0.08*
WfD																		
L2	91	0.88	9.87	-24	19	0	-18	15	91	1.53	9.64	-24	22	0	-18	17	0.65	0.66
L3	81	8.14	7.43	-11	21	9	-3	18	89	9.72	6.92	-11	24	12	-3	17.6	1.58	0.15
L4	62	9.34	7.12	-2	24	9.5	-1	21	83	12.45	6.81	-10	27	14	1	23.7	3.11	**0.009**
L5	70	10.73	5.20	0	20	11	2.45	19	78	12.72	4.94	-3	23	13.5	4.85	20.2	1.99	**0.02**
R2	99	1.42	9.36	-25	19	0	-15	16	92	-2.86	9.39	-25	19	-1.5	-19	13.5	-4.28	**0.002**
R3	92	9.45	6.43	-6	22	12	-1.5	17	90	9.00	6.96	-5	21	10.5	-1.6	19	-0.45	0.66
R4	69	9.96	7.10	-7	26	9	0	22.6	80	9.33	7.01	-10	23	8	0	21	-0.63	0.59
R5	72	11.50	5.46	-1	23	11.5	2.55	19.5	79	11.23	4.92	1	22	11	2.9	20.1	-0.27	0.75

Descriptive statistics of ridge counts (Table 2) showed systematically higher values of RCr in males on the left hand and the difference was significant on the L4 an L5. On the right hand the sex differences were neither systematic nor significant. On the contrary, mean values of RCu were systematically higher in males on the right hand and the difference was significant on the R2. On the left hand the sex differences were neither systematic nor significant. On the left hand, WfD mean values were always higher in males than in females, while on the right hand, they were always higher in females. The sex difference in WfD was highest on L4 (higher in males) and R2 (higher in females) and significant on fourth and fifth finger of the left hand (L4, L5) and the second finger of the right hand (R2). No significant sex differences were found for BfD (Table 3), except for borderline significance for BfDr of R2-R4 and R2-R5 difference (higher in females) and for BfDu of R2-R3 (higher in males).

Table 3. Descriptive statistics and tests of sex differences in BfD. Descriptive parameters of between-finger ridge count differences (BfD) for each finger and sex separately; for legend see Table 2

	Females								Males									
Difference	N	Mean	SD	Min	Max	Med	Q05	Q95	N	Mean	SD	Min	Max	Med	Q05	Q95	Sex Diff	p-value
BfDr																		
L2-L3	70	-2.93	6.25	-20	12	-2	-13	5	82	-4.26	7.17	-23	13	-3	-16	4.95	-1.33	0.23
L2-L4	55	-5.64	6.98	-26	12	-4	-19	2.3	79	-7.67	7.72	-27	15	-6	-21.1	2.1	-2.03	0.12
L2-L5	63	-4.37	5.99	-21	10	-4	-14.9	3.9	73	-4.96	7.42	-18	12	-5	-16.4	5.4	-0.59	0.61
L3-L4	58	-3.34	5.48	-18	13	-2	-13.3	3.15	77	-4.32	5.09	-19	9	-4	-13.2	3	-0.98	0.29
L3-L5	58	-1.64	5.67	-20	8	-0.5	-12.5	6	70	-0.43	5.76	-21	15	0	-9	8	1.21	0.24
L4-L5	58	1.72	4.73	-15	12	2.5	-5.15	8.15	69	3.16	5.05	-13	14	3	-6.6	10	1.44	0.11
R2-R3	80	-4.03	5.65	-18	8	-3	-14.1	4.05	82	-5.79	7.90	-24	15	-3	-18.9	3	-1.77	0.11
R2-R4	67	-7.52	7.00	-25	6	-7	-21	1.7	73	-9.74	7.35	-25	2	-8	-21	0	-2.22	*0.07*
R2-R5	67	-4.81	6.15	-21	10	-5	-15.4	4	68	-6.87	6.29	-19	7	-7.5	-16.7	2	-2.06	*0.06*
R3-R4	64	-3.23	5.12	-20	8	-3	-11.9	3.85	78	-4.76	5.91	-23	8	-4	-13.8	4.15	-1.52	0.11
R3-R5	62	-1.18	5.51	-16	9	-1	-12.9	6	73	-1.41	6.23	-22	8	0	-13.4	5.4	-0.23	0.83
R4-R5	58	2.03	5.01	-13	16	2	-4.3	9.45	69	2.42	5.15	-11	13	3	-6	11	0.39	0.67
BfDu																		
L2-L3	70	3.50	7.37	-11	24	0	-4.55	18	82	3.88	8.39	-20	26	0	-5.9	18.95	0.38	0.77
L2-L4	55	1.89	7.75	-16	19	0	-10.8	15.6	78	3.35	8.54	-15	24	1	-11.2	19	1.46	0.32
L2-L5	62	4.79	6.45	0	20	0.5	0	17	73	6.21	7.96	-3	30	3	0	19	1.42	0.27
L3-L4	58	-1.70	6.44	-22	18	0	-15	6.15	76	-1.70	6.29	-17	23	0	-11.3	7.25	0.00	1.00
L3-L5	57	1.56	5.11	-10	18	0	-4	12.8	70	1.23	5.30	-11	23	0	-4.1	13.1	-0.33	0.74
L4-L5	57	2.84	4.97	-4	16	0	0	12.6	68	2.72	5.15	-5	18	0	0	14.65	-0.12	0.90
R2-R3	80	4.14	7.84	-17	23	0	-2	20	82	6.37	7.97	-13	23	2.5	-0.95	19.95	2.23	*0.07*
R2-R4	67	0.90	6.86	-17	21	0	-9.4	11.7	73	1.67	9.02	-24	24	0	-11.4	16.4	0.78	0.57
R2-R5	66	5.35	8.10	-15	21	0	0	20	68	6.91	7.78	-9	24	3.5	0	20	1.56	0.26
R3-R4	64	-3.17	6.43	-17	22	0	-14.9	0	78	-4.45	6.83	-20	12	0	-16.2	3.15	-1.28	0.26
R3-R5	61	1.21	5.83	-10	23	0	-1	16	73	0.81	5.84	-13	23	0	-8.6	12.8	-0.40	0.70
R4-R5	58	4.00	5.72	0	20	0	0	15.15	69	5.32	6.53	0	24	2	0	16.6	1.32	0.23

In females, directional asymmetry (Table 4) of RCr (DAr) was on average positive (higher values on the right hand) on all fingers but the differences did not significantly differ from zero (except for borderline significance for R4-L4), while in males it was on average negative (higher values on the left hand) in all fingers and the differences were significant on the second fingers (R2-L2). In females, directional asymmetry of RCu (DAu) significantly differed from zero only on the third fingers (R3-L3), while in males the third finger was almost symmetrical but not on the remaining fingers where the DAu differed from zero (significant for R2-L2 and R4-L4 and borderline significant for R5-L5). Sex differences in DAr were negative (i.e., lower – leftward dominated RCr – in males than in females) for all four fingers, while

sex differences in DAu were positive (i.e., higher – rightward dominated RCu – in males than in females) in all fingers, and these sex differences were mostly statistically significant, except for the non-significant results for the third fingers (R3-L3) and marginal result of DAu in the fifth finger (R5-L5).

Table 4. Descriptive statistics and sex differences in DA. Descriptive parameters and tests of sex differences in directional asymmetry in ridge counts (DAr, DAu) for each finger and sex separately; DA p-value – significance of the one sample permutation test between mean value of DA and zero (two-sided hypothesis); for legend see Table 2

	Females									Males									
Difference	N	Mean	SD	Min	Max	Med	Q05	Q95	DA p-value	N	Mean	SD	Min	Max	Med	Q05	Q95	DA p-value	Sex Diff	p-value
DAr																				
R2-L2	83	0.22	5.52	-12	19	0	-8.8	9.9	0.74	82	-2.18	7.64	-20	19	-1	-16	12	**0.012**	-2.40	**0.023**
R3-L3	74	0.32	4.67	-12	14	0	-7.35	7	0.57	82	-0.99	5.47	-19	13	0	-10	5	0.11	-1.31	0.11
R4-L4	56	0.95	3.89	-10	14	1.5	-6	6	*0.08*	70	-0.67	4.88	-18	7	0	-9.55	5.55	0.27	-1.62	**0.048**
R5-L5	53	0.64	3.05	-8	10	1	-3.4	4.8	0.14	68	-0.66	3.28	-11	7	-0.5	-5	4.65	0.11	-1.30	**0.028**
DAu																				
R2-L2	83	-0.34	6.73	-20	21	0	-12.8	11.8	0.66	82	2.43	7.27	-19	20	0	-6	15.95	**0.0034**	2.76	**0.012**
R3-L3	74	-1.27	5.38	-22	17	0	-12.7	0	**0.047**	82	0.01	6.27	-23	23	0	-7.95	12.7	1.00	1.28	0.18
R4-L4	56	0.68	5.12	-15	15	0	-7.5	9.25	0.34	69	2.88	6.22	-10	17	0	-7	15.6	**0.00021**	2.21	**0.036**
R5-L5	52	-0.19	2.35	-9	10	0	-2.9	0.45	0.62	68	0.79	3.29	-8	13	0	-1	9	*0.051*	0.99	*0.07*

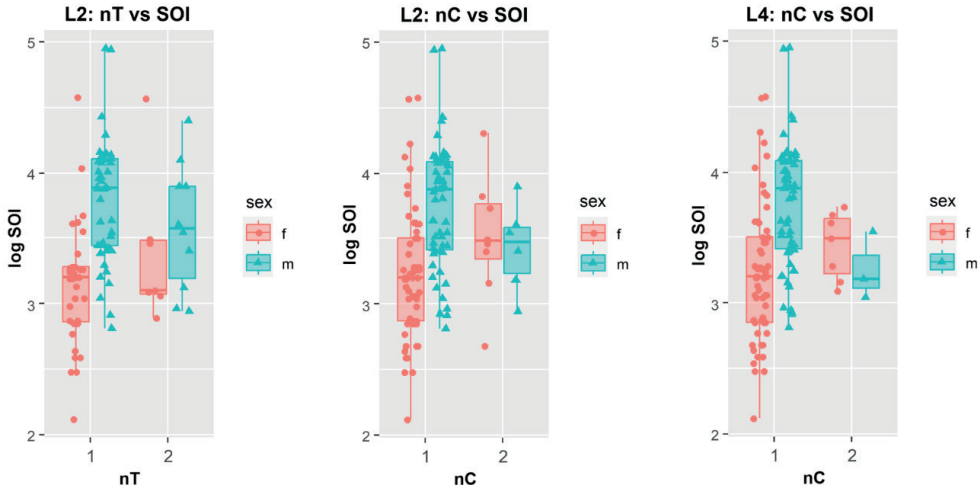

Fig. 2. Significant effects of numbers of triradii and cores. Box-plot visualization of significant effects of nT (number of triradii category) and nC (number of cores category) on logSOI in L2 and L4 fingers; log SOI – natural logarithm of SOI score, 1 – lower number of triradii or cores category, 2 – higher number of triradii or cores category, f – females (red dots), m – males (blue triangles), thick horizontal – median, boxes – lower and upper quartiles, whiskers – non outlier ranges

Relationships between SOI and numbers of triradii and cores

Robust analysis of variance found some significant effects of sex and nT and nC on sociosexuality variables (Table 5). When testing the effect of sex and nT on SOI, the effect of sex was always highly significant, which indicates systematic differences in SOI between sexes. No effects of nT were recorded in any of the fingers but significant interaction between sex and nT was found in the L2 (Figure 2). While in bearers of lower number of triradii on the L2 finger (nT=1) clear sex difference in SOI was evident, in bearers of higher number of triradii (nT=2) on L2 average sex difference was not expressed – males had on average lower SOI than those with lower number of triradii, while females had higher mean SOI than those with lower nT. Such effects were not found on the right hand.

Table 5. Results of the Robust Analysis of Variance (RAOV) for the effect of number of triradii and cores on SOI. Tests of effects of nT (nC) and sex to SOI, including interaction of both factors (nT : sex, and nC : sex); Mean RD – mean reduction in residual dispersion

	nT			sex			nT : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0674	0.313	0.6	3.6054	16.728	**0.0001**	2.2269	10.332	**0.0017**
L3	0.0049	0.020	0.9	3.9575	15.732	**0.0001**	0.2793	1.110	0.3
L4	0.0260	0.103	0.7	6.0322	23.905	**0.00001**	0.0482	0.191	0.7
L5	0.1211	0.494	0.5	2.8935	11.815	**0.0008**	0.0288	0.118	0.7
R2	0.3237	1.330	0.3	6.2225	25.568	**0.00001**	0.1727	0.710	0.4
R3	0.6591	2.818	*0.1*	3.5278	15.084	**0.0002**	0.3102	1.326	0.3
R4	0.0300	0.117	0.7	7.9123	30.842	**0.00001**	0.1156	0.451	0.5
R5	0.1252	0.470	0.5	4.1274	15.490	**0.0001**	0.0025	0.009	0.9
	nC			sex			nC : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0011	0.004	0.9	0.8397	3.530	0.06	1.4770	6.209	**0.014**
L3	0.0824	0.335	0.6	2.9651	12.040	**0.001**	0.1735	0.704	0.4
L4	0.1559	0.679	0.4	0.3935	1.713	0.2	1.4117	6.146	**0.014**
L5	0.1230	0.493	0.5	0.5452	2.184	0.1	0.3469	1.389	0.2
R2	0.1324	0.546	0.5	2.2843	9.413	**0.003**	0.0607	0.250	0.6
R3	0.4897	1.967	0.2	1.4380	5.777	**0.018**	0.0155	0.062	0.8
R4	0.0078	0.033	0.9	0.4571	1.902	0.2	0.7521	3.130	*0.1*
R5	0.1801	0.717	0.4	0.8873	3.531	0.06	0.0025	0.010	0.9

Similar results were found for nC. No simple effect of nC was found in any of the fingers, however, in L2 and L4 significant interactions of nC with sex were found, similar to the nT described above. While in cases with

more obvious patterns – those with lower number of cores (nC=1) – average sex difference in SOI was clearly evident, in the group with higher number of cores (nC=2) sex difference in SOI was blurred (females have higher SOI and males lower than those typical for a given sex).

Table 6. Results of the Robust Analysis of Variance (RAOV) for the effect of ridge count on SOI. Tests of effects of ridge count variables (RCr, RCu, and WfD) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion

	RCr			sex			RCr : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0354	0.148	0.70	8.3741	35.037	**0.00001**	0.6002	2.511	0.12
L3	0.0002	0.001	0.98	4.5894	17.689	**0.0001**	0.3838	1.479	0.23
L4	0.7573	3.147	*0.08*	4.5125	18.753	**0.0001**	0.4974	2.067	0.16
L5	0.0146	0.058	0.81	4.1555	16.498	**0.0001**	0.3065	1.217	0.27
R2	0.7108	3.055	*0.08*	8.3507	35.889	**0.00001**	0.9374	4.029	**0.048**
R3	0.0532	0.199	0.66	4.5665	17.107	**0.0001**	0.5787	2.168	0.14
R4	0.0176	0.068	0.80	4.3293	16.763	**0.0001**	0.1725	0.668	0.42
R5	0.0075	0.031	0.86	4.4246	18.040	**0.0001**	0.2078	0.847	0.36
	RCu			sex			RCru : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.0435	0.202	0.65	7.5957	35.309	**0.00001**	1.0380	4.825	**0.031**
L3	0.0972	0.372	0.54	3.0799	11.784	**0.001**	0.0227	0.087	0.77
L4	0.0540	0.215	0.64	3.6591	14.586	**0.0003**	0.0534	0.213	0.65
L5	0.0192	0.079	0.78	1.7089	7.043	**0.01**	0.3238	1.334	0.25
R2	0.0186	0.084	0.77	7.7769	34.884	**0.00001**	0.2853	1.280	0.26
R3	0.3725	1.363	0.25	1.9502	7.134	**0.0091**	0.0001	0.000	0.99
R4	0.1306	0.522	0.47	5.1347	20.545	**0.00001**	0.6090	2.437	0.12
R5	0.0000	0.000	1.00	1.0912	4.507	**0.038**	0.0014	0.006	0.94
	WfD			sex			WfD : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2	0.1147	0.543	0.46	8.5122	40.316	**0.00001**	1.1944	5.657	**0.019**
L3	0.0136	0.051	0.82	4.2212	15.735	**0.0002**	0.2777	1.035	0.31
L4	0.6735	3.021	*0.09*	3.8188	17.133	**0.0001**	0.7448	3.342	*0.07*
L5	0.0760	0.290	0.59	4.2065	16.039	**0.0002**	0.1904	0.726	0.40
R2	0.1215	0.525	0.47	8.0434	34.759	**0.00001**	0.6001	2.593	0.11
R3	0.0707	0.273	0.60	4.0687	15.732	**0.0002**	1.0722	4.146	**0.045**
R4	0.5411	2.124	0.15	4.2232	16.575	**0.0001**	0.0162	0.064	0.80
R5	0.0803	0.340	0.56	4.7632	20.174	**0.00001**	0.2057	0.871	0.35

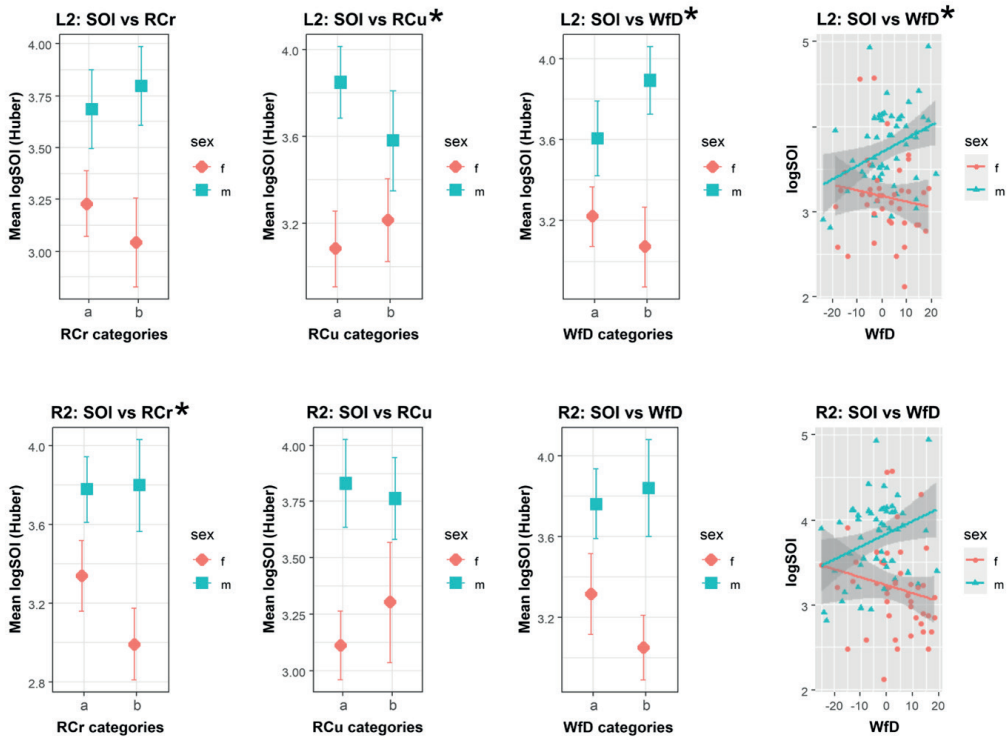

Fig. 3. Significant effects of ridge counts. Plots of effects of RCr, RCu, and WfD categories on logSOI in the second finger (L2 and R2); first three left columns: Huber mean estimates (females – red dots, males – blue squares) augmented with Wald type 95% confidence intervals, a – lower values category, b – higher values category; right column: identical data in raw values of WfD for a comparison (females – red dots, males – blue triangles, lines – ordinary linear least squares regression models, shadow zones – 95% confidence intervals), asterisks – significant interaction between sex and dermatoglyphic variable

Relationships between SOI and ridge counts and within-finger differences in ridge counts

In all tests (Table 6), sex again revealed significant effect on SOI while RCr revealed only borderline effect on L4 (p-value =0.08). However, significant interaction between sex and RCr was found for R2 – the higher was RCr, the higher was SOI difference between sexes. Similarly, significant interaction between sex and RCu was found on L2 for RCu. As can be seen in Figure 3, in both hands, effects of RCu and RCr are similar, but opposite in their direction, which, in connection of both, creates a radioulnar continuum. This is well expressed in WfD variables and more visible on several fingers and significant interactions between WfD and sex was found both on L2 and R2.

Relationships between SOI and between-finger differences in ridge counts

None of the tested relationships between RCr BfDs and SOI was statistically significant (Table 7), except for borderline significance – p-value=0.0951 – of the interaction of both factors (sex : BfD) in L3-L4 difference. In RCu BfD, significant interactions of factors (sex : BfD) on SOI were found in L2-L4 and R3-R4 differences (Figure 4). Similarly, to the WfDs, the higher was the between-finger differences in RCu on the above-mentioned pairs of fingers, the less typical (lower in males and higher in females) the SOI was (Figure 4).

Table 7. Results of the Robust Analysis of Variance (RAOV) for the effect of BfDs on SOI. Tests of effects of between-finger RC differences (BfDr and BfDu) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion; NA – not available (numerical condition not met)

	BfDr			sex			BfDr : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2-L3	0.0358	0.1381	0.7114	4.9372	19.0572	**0.00001**	0.0000	0.0000	1.0000
L2-L4	0.0000	0.0000	1.0000	3.0192	12.3281	**0.0009**	0.0069	0.0283	0.8671
L2-L5	0.1149	0.4624	0.4993	5.0780	20.4311	**0.00001**	0.0549	0.2208	0.6403
L3-L4	0.0721	0.2536	0.6166	3.6202	12.7266	**0.0008**	0.8213	2.8874	*0.0951*
L3-L5	0.1625	0.6994	0.4073	3.9136	16.8401	**0.0002**	0.4473	1.9249	0.1720
L4-L5	0.5128	2.6216	0.1124	5.0871	26.0088	**0.00001**	0.0025	0.0125	0.9114
R2-R3	0.0125	0.0486	0.8262	5.5452	21.5011	**0.00001**	0.2177	0.8442	0.3613
R2-R4	0.0032	0.0129	0.9101	4.1369	16.6641	**0.0001**	0.4128	1.6628	0.2023
R2-R5	0.4118	1.8841	0.1757	3.6669	16.7793	**0.0001**	0.1330	0.6086	0.4388
R3-R4	0.1871	0.6760	0.4143	2.8806	10.4054	**0.0021**	0.0016	0.0058	0.9397
R3-R5	0.2286	0.9324	0.3390	2.8953	11.8087	**0.0012**	0.0003	0.0011	0.9736
R4-R5	0.0769	0.4116	0.5242	5.6775	30.3920	**0.00001**	0.2436	1.3040	0.2591
	BfDu			sex			BfDu : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
L2-L3	0.1018	0.4082	0.5251	4.6857	18.7803	**0.0001**	0.3351	1.3432	0.2506
L2-L4	0.6057	2.6901	0.1067	3.9779	17.6682	**0.0001**	1.7632	7.8316	**0.0071**
L2-L5	0.0069	0.0305	0.8621	5.2166	23.0112	**0.00001**	0.6944	3.0632	*0.0856*
L3-L4	0.0990	0.3856	0.5373	2.2959	8.9400	**0.0042**	0.0231	0.0898	0.7656
L3-L5	0.4797	1.9548	0.1688	1.1382	4.6382	**0.0365**	0.0868	0.3537	0.5549
L4-L5	0.0188	0.0766	0.7832	4.8364	19.6977	**0.0001**	0.2972	1.2105	0.2771

Table 7 (cont.)

	BfDu			sex			BfDu : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-R3	0.0159	0.0654	0.7990	4.9122	20.2178	**0.00001**	0.0185	0.0763	0.7832
R2-R4	0.5835	2.3458	0.1310	3.9917	16.0473	**0.0002**	0.0105	0.0422	0.8380
R2-R5	0.1366	0.6327	0.4299	5.7145	26.4600	**0.00001**	0.1119	0.5180	0.4749
R3-R4	0.0141	0.0525	0.8196	3.4616	12.9299	**0.0007**	1.1326	4.2306	**0.0442**
R3-R5	NA	NA	NA	NA	NA	NA	NA	NA	NA
R4-R5	0.0107	0.0494	0.8250	6.0558	28.0016	**0.00001**	0.4206	1.9448	0.1696

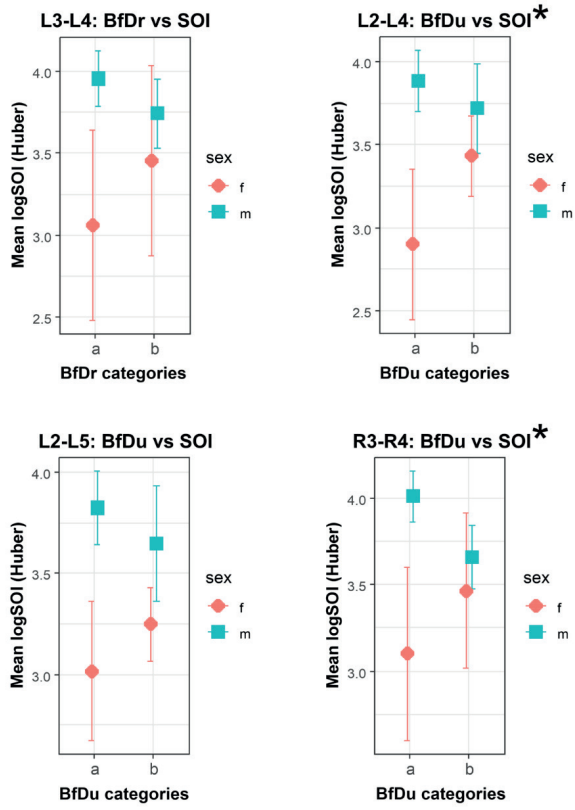

Fig. 4. Significant effects between fingers. Plots of effects of BfD (between-finger differences in ridge count) categories on logSOI the specified finger pair; Huber mean estimates (females – red dots, males – blue squares) augmented with Wald type 95% confidence intervals, a – lower values category, b – higher values category

Relationships between SOI and directional asymmetry in ridge counts

When studying relationships between directional asymmetry (Table 8) of ridge counts and SOI, a statistically significant interaction between the effect of sex and DAr was found on the third fingers (DAr R3-L3), along with borderline significance of interaction between the effect of sex and DAu on third fingers (DAr R3-L3). In both effects, cases with more rightward dominated asymmetry (both DAr and DAu) had more typical sex differences in SOI (higher values in males and lower in females) while leftward asymmetrical patterns belonged to cases in which the sex differences in SOI disappeared.

Table 8. Results of the Robust Analysis of Variance (RAOV) for the effect of DA on SOI. Tests of effects of directional asymmetry (DAr and DAu) to SOI, including interactions of dermatoglyphic variables with sex; Mean RD – mean reduction in residual dispersion

	DAr			sex			DAr : sex		
Difference	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-L2	0.1584	0.7157	0.4001	8.20195	37.0688	**0.00001**	0.1146	0.5179	0.4739
R3-L3	0.2949	1.1475	0.2880	3.4734	13.5140	**0.0005**	1.8598	7.2361	**0.0090**
R4-L4	0.0147	0.0599	0.8077	2.2046	9.0085	**0.0043**	0.3599	1.4707	0.2313
R5-L5	0.0124	0.0549	0.8159	4.3975	19.5095	**0.0001**	0.0875	0.3880	0.5367
	DAu			sex			DAu : sex		
Finger	Mean RD	F-value	p-value	Mean RD	F-value	p-value	Mean RD	F-value	p-value
R2-L2	0.1527	0.6748	0.4138	6.7970	30.0330	**0.00001**	0.0464	0.2049	0.6520
R3-L3	0.0150	0.0528	0.8190	3.0840	10.8790	**0.0016**	0.1064	0.3754	0.5422
R4-L4	0.1759	0.7206	0.4002	3.2135	13.1687	**0.0007**	0.8570	3.5121	*0.0672*
R5-L5	0.0851	0.3769	0.5426	1.8100	8.0122	**0.0071**	0.0320	0.1416	0.7086

Discussion

Main recorded effects

In this study, we attempted to search for dermatoglyphic correlates of human sociosexuality. Inspired with previous promising indications of validity of within-individual (between-fingers) contrast in searching for sex differences (Polcerová et al. 2023; 2022a) and environmental factors (Kahn et al. 2001; 2008) we tested several types within-individual dermatoglyphic differences (within fingers, between-finger within-hand, and between-finger between-hand asymmetry) and their effect on log(SOI) score values. Recorded SOI scores and their sex differences were in congruence with previously published studies for Czech and Slovak population samples (Ingrová et al. 2018; Schmitt 2005). Also, dermatoglyphic variation in pattern frequencies and ridge count values did not exceed obvious limits of typical human variations. Therefore, our analyses are based on common and in no way exceptional data.

We found that males with more complex patterns on the second finger tended to occupy the lower part of the male SOI

score distribution, while the opposite was true for females. Other results showed something similar for differences in the number of ridges within and between fingers on (mostly) L2 and L4: the more radial the contrast, the more blurred the sex difference was due to the shift of SOI scores to lower values in males and to higher values in females. Therefore, some sort of mechanism connects dermatoglyphics on fingers with SOI but remarkably often (though not exclusively), the 2nd and 4th fingers appeared in various dermatoglyphic features in which a significant effect was found. This applies both for sex differences and relationships with SOI. A unique nature of the 2nd finger was recognized for a long time in dermatoglyphics since it bears one order (or even more) higher frequencies of radially oriented patterns, mostly radial loops and whorls with radial within-pattern asymmetry compared to other fingers (Cummins and Midlo 1961: 67). The second finger is therefore the most variable finger of all in respect to the complexity and radio-ulnar variation of dermatoglyphic patterns it bears. This underlies a relatively wide range of variations that can express an influence of ontogenetic factors. The 4th finger bears relatively high proportion of central pocket patterns (Cummins and Midlo 1961) – their variable within-finger asymmetry also allows relatively wide variation of within-pattern radioulnar differences.

Interpretation of the results

It has been suggested that dermatoglyphics is associated with sex-specific behavior based on the fact that the brain and dermatoglyphics arise from the same prenatal ectoderm and that nerve cell migration occurs at the time epidermal ridges are formed (Fatjó-Vilas et al. 2008; Vonk et al. 2014). Therefore, prenatal factors, both genetic and environmental, could simultaneously affect both structures – dermatoglyphics and brain substrate for a behavior – and consequently lead to their nonrandom associations. Although other associations between dermatoglyphics and psychological features have been found (Akbarova 2018) our study is the only one known to us where association between SOI and dermatoglyphics has been detected. From the prevalent involvement of the 2nd and 4th fingers we cannot avoid an impression that the results describe an analogous situation to one that can be found in the ratio between the length of the 2nd and 4th fingers, or digit ratio, which is widely studied as a putative marker of prenatal sex steroids (recently e.g., Kasielska-Trojan et al. 2024).

In dermatoglyphics, males have usually on average more complex patterns on fingers (higher nT and nC) and larger patterns (Cummins and Midlo 1961:273), which means higher Total Finger Ridge Count (TFRC) (Holt 1961; 1979). If testosterone is the main factor of masculinization of these dermatoglyphic features and, at the same time, is also responsible for masculinization of brain dispositions for sociosexuality, increasing "masculinity" of the dermatoglyphic features should be positively correlated with increasing "masculinity" (higher scores) of SOI. Our result for numbers of triradii and cores are in congruence with this potential explanation in females but not in males where the opposite is true. It is difficult to discuss a congruence of our results of the ridge-count features (quantitative features) with assumptions about prenatal testosterone and ridge count, since most frequently published TFRC results are sums of ridge counts of all ten fingers and variations between

individual fingers as well as within fingers is lost/dissolved in these summary variables (Jantz 2022; Polcerová et al. 2022a). From the published studies, we found no clue or assumption about the possible relationship of RCu or WfD with TFRC. So, we are not able to predict from the previously published studies if the correlation of e.g. RCu on L2 and SOI scores should be expected to be mild or strong, positive or negative. Changes in average radioulnar within-finger asymmetries compared to healthy population is frequently on the list of dermatoglyphic markers of genetic diseases. The frequency of radial loops is increased in many genetic syndromes and their abundance can be shifted to other than the 2nd finger, e.g., in Down syndrome frequently to the 4th finger (Schaumann and Alter 1976: 55), in trisomy of the chromosome 18 to the first, third and fifth fingers (Schaumann and Alter 1976: 165).

We can hypothesize that except for serious pathological variations in dermatoglyphic patterns related to genetic syndromes or harsh environmental factors, radioulnar and body side variation in dermatoglyphic features vary more inconspicuously due to less serious ontogenetic factors even within normal range of variation in an otherwise healthy population. Unfortunately, radio-ulnar asymmetry of whorl patterns is rarely expressed in results of studies following traditional dermatoglyphic methodology. Therefore, in our opinion, many effects related to radio-ulnar asymmetries within fingers remained obscured. The only possible clue can be the frequencies of *radial loops* – their frequencies on 2nd fingers are traditionally published and their abundance on other fingers are so small that even without dividing results into individual fingers frequencies of radial loops in total of all ten fingers (in normal healthy population) reflect almost exclusively the second fingers. However, we found only one study which put radial loops in relation with steroid hormones. In a study of 54 males with sex hormones anomalies (Al-Jumaily et al. 2010), increased frequency of radial loops was found in the studied group compared to controls. Unfortunately, no detailed description of etiologies of these "hormonal anomalies" was available in this study so we cannot discuss it further. Since hormonal anomalies in males are mostly characterized by lower levels of steroid hormones (rather than higher), we can assume that higher frequencies of radial loops were found in a group of subjects with prevalently lower steroid levels which would be in congruence with our results (low WfD related to low SOI) in males. This does not agree, however, with our results in females but these were not involved in the discussed study (Al-Jumaily et al. 2010).

Directional/side asymmetry (right-left) in our sample is in congruence with previous studies (Kunter and Rühl 1995) – males in our sample were generally more asymmetrical than females, except for the third finger which is more symmetrical (in males DA for RCu was effectively zero). However, the male asymmetry was opposite on both sides of fingers – RCr in males was leftward asymmetrical while RCu was rightward asymmetrical. In males, the most asymmetrical RCr were on the second fingers and RCu on the 2nd and the 4th fingers. In females the asymmetry was lower and differently structured between fingers. However, highest sex differences in the side asymmetry were on the 2nd and 4th fingers both for RCr and RCu. Previous studies found a relationship between right-left directional asymmetry of dermatoglyphic

TFRC (i.e., size of patterns and prevalence of large patterns – mostly whorls) and sex-dimorphic cognitive tasks (brain lateralization); the more right directed asymmetry – the better scoring in male-favoring tasks (Kimura and Carson 1995; Kimura and Clarke 2001; Sanders et al. 2002). In our sample and methodology, however, relationships between SOI and DA were different in different fingers (and radial vs. ulnar finger sides) and not significant, except for significant interaction between asymmetry of radial ridge–count on the 3rd finger which was in congruence with the above-mentioned principle (more masculine with more right-directed values) only in males, but not females.

Since we are not aware of any study focusing on the relationship between sociosexuality and dermatoglyphics, we can only compare our results with studies of the relationship between SOI and the 2D:4D ratio (which is *de facto* a radioulnar contrast of the lengths of the respective fingers). Clark (2004) in his second study found a negative correlation between 2D:4D ratio and SOI on both the right and left hands in women (consistent with the prediction from the considered effect of prenatal androgenization), the relationship was statistically significant on the right hand only. He found a similarly significant relationship in his 3rd study (Clark 2004). In a study by Charles and Alexander (2011), in males, SOI did not correlate with the 2D:4D ratio on either the right or left hand (but correlation coefficient values were positive and higher for the left). In females the correlation was significant but positive (the more feminine digit ratio the higher SOI) which contradicts the prediction from the theory of prenatal androgenization. In women in study by DeLecce et al. (2014), SOI did not correlate with the 2D:4D ratio on either the right or left hand. Therefore, the results of these studies (Clark 2004; Charles and Alexander 2011; DeLecce et al. 2014) do not show a clear relationship between 2D:4D ratio and SOI logically predictable by the theory of prenatal androgenization. This is also true more generally for the relationship between 2D:4D ratio and sex-typicality in behavior which has also been discussed previously in some studies (Cohen-Bendahan et al. 2005; Wong and Hines 2016). As in these studies, we can now only speculate that the differences in the results may be due to differences in the relative timing of hand and brain development between the two sexes, body sides, and different human populations. Some studies show a greater effect of androgens on the right side of the body than the left, as well as stronger relationships between behaviors with 2D:4D ratios on the right hand than on the left (e.g., Manning et al. 1998). Studies of ridge-count radioulnar contrasts clearly show significantly greater and more consistent dimorphism on the right hand compared to the left (Polcerová et al. 2022a; 2022b; Polcerová et al. 2023). Our present study of the relationship between radioulnar contrasts and SOI, similar to the 2D:4D ratio studies mentioned above) also suggests ambiguity about which side of the body has a stronger relationship with SOI, but the sense of that relationship is consistent across both hands (see further discussion of stress).

Since direct effects of doses of genes in sex chromosomes was accepted as the cause of dimorphism in dermatoglyphics (Penrose 1967), an alternative explanation of the relationships between dermatoglyphics and SOI as found in our study could be explained exclusively on the

genetic level. Some gene variants could predispose their bearers both to specific SOI and, as a side effect, specific dermatoglyphics. Recently, several particular genes have been specified directly (Ho et al. 2016) at the molecular level to be involved in specific finger dermatoglyphics, especially the gene ADAMTS9-AS2 (chromosome 3, locus 3p14.1) was identified as important in the formation of *whorl patterns* (i.e., patterns prevailing in subject with SOI not typical for a given sex). However, relationship of this gene with whorls were recognized not only for the 2nd finger but for other fingers (except for the thumb) and, thus, it does not explain our results dominated with effects on the 2nd and 4th fingers. Moreover, since this gene (and most of other genes recognized as significant in the cited study (Ho et al. 2016)) is not located on sex chromosomes we cannot avoid the need for an additional explanation why the effect of dermatoglyphics on SOI is opposite in each sex. It needs to be clarified whether the same genes also play a role in brain development (and functioning) of neuronal circuits regulating sociosexuality. Since Bailey et al. (2000) found relatively strong within-family additive genetic components in sociosexuality while little effect of shared environmental component on sociosexuality was observed, further searching for common molecular-genetic factors of whorls patterns on fingers and sociosexuality is a potential option.

Finally, we can open another interpretation line concerning prenatal stress. It is well known that prenatal stress and/or various disruptors of prenatal development can compromise fully/optimal expression of many developing processes (Gluckman and Hanson 2006), including testosterone levels and sex differences of stress effects (e.g. Barrett et al. 2014). In rats, for instance, prenatal stress during the late gestational period can lead to demasculinization of male sexual behavior in adulthood (Coll-Andreu et al. 1989; Velazquez-Moctezuma et al. 1993) and masculinization in behavior of affected females (Del Cerro et al. 2015; Kinsley and Bridges 1988). These studies in recent years have flourished within the frame of DOHaD concept (Developmental Origins of Health and Disease) also in humans. For instance, prenatal exposure to *phenol* was negatively associated with umbilical cord serum levels of testosterone (Liu et al. 2016), and, similarly, maternal urinary level of bisphenol A was negatively associated with the left hand 2D:4D ratio of their daughters (Guo et al. 2021). We can therefore assume, that various environmental insults can, more or less – on a continuous scale compromise the sex-typical levels of testosterone (and more generally – typical genes – steroid hormones milieu and interactions for a given sex) and coping with and/or adaptation to these changes might include complex shifts both in morphology and behavior. We can notice only one example of an old evidence mentioned by Cummins and Midlo for two different previously published populations – for associations between dermatoglyphics and schizophrenia which offered results similar to ours for SOI: while typical sex differences in whorls patterns frequencies were found in controls, in schizophrenic patients sex differences were blurred – in males whorl frequencies were lower and in females they were higher (Cummins and Midlo 1961:277). A similar pattern is represented by the effect of birth order (the increase of which can be understood as a worsening of complex prenatal conditions) on the 2D:4D ratio (Králík et al. 2019a), where the greatest dimorphism

was observed in first-borns, and as birth order increased (in secondborns and third and higher-borns), there was an increase (feminization) of the 2D:4D ratio in males and a decrease (masculinization) of the 2D:4D ratio in females, which blurred to completely reversed the sexual dimorphism of this trait. Thus, we can speculate that our results of the relationship between dermatoglyphic radioulnar contrasts and SOI show something similar: under normal conditions, a typical dermatoglyphic dimorphism is established while simultaneously setting up a disposition for sex-typical sociosexuality. Alteration of typical prenatal hormone levels for a given sex (e.g., due to stress) alters the timing of fetal pad development on hands and feet, resulting in altered dermatoglyphic traits on them (larger patterns and negative radioulnar contrasts) and concomitant lack of dimorphism in SOI in this group.

Limitations of the study

One of the limitations of our study is the sample size. Despite original sample size (N=180), readability of the dermatoglyphic patterns and/or especially the individual ridges for ridge-counting was limited in some fingers due to sweat produced by skin during scanning and/or excessive pressure imposed to fingers. In a combination with missing data in SOI (all 7 items should be filled for SOI score, which was not always the case) the final sample size in most of the comparisons was usually lower than one hundred subjects.

The results of our study are limited only to this within-population variation and should not be applied to other populations without caution. Human populations differ both in the radioulnar tendencies of the dermatoglyphic patterns on fingers (e.g., in frequencies of radial loops) and SOI scores and there is absolutely no certainty that these within-population relationships apply also in a between-population comparison. In other words, we cannot say that a difference in WfD on the L2 between two populations would be followed with the same change of SOI like the same change of WfD between two groups within our studied population.

Another limitation of our study is the unavailability of data from the 1st finger due to method of hand scanning. The one-off nature of the examination of the volunteers did not allow us to undergo repeated measurements (hand scanning and imprinting) and proceed SOI assessment. Finally, we have not found any reference study of SOI in relationship with dermatoglyphics so far, so we cannot compare our result with any other study.

Conclusions

In our study we found that relationships between finger dermatoglyphics and SOI exist. As hypothesized, these relationships manifested also in radioulnar ridge-count differences (radioulnar contrasts), but not in their whole spectrum. Relationships were observed only in some of the differences related to specific fingers, mostly in the 2nd and 4th fingers. Whatever prenatal factors are involved in the SOI dispositions they should be also somehow involved in development of fetal volar pads and specific coincidence of their regression with onset of histological differentiation of primary dermal ridges (Mulvihill and Smith 1969; Kücken 2007).

Additional information

Supplementary materials [online version].

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Conflict of interests

The authors declare no conflict of interests.

The manuscript has not been previously published or concurrently submitted to an editorial office of another journal. The manuscript was approved by all authors and the institutions where it was developed.

Authors' contribution

Pavlína Ingrová: study design and conception, data collection, data analysis, manuscript preparation; Miroslav Králík: study design and conception, funding, data analysis, manuscript preparation; Lenka Polcerová: data analysis, manuscript preparation; Věra Pavlíková: data collection, manuscript preparation; Ondřej Klíma: software development, manuscript preparation; Martin Čuta: data analysis, manuscript preparation.

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