Early Human Development 151 (2020) 105159

Contents lists available at ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Assortative mating and digit ratio (2D:4D): A pre-registered empirical study and meta-analysis

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ARTICLE INFO

Keywords:
2D:4D
Assortative mating
Behavioural genetics
Digit ratio
Foetal testosterone
Mate choice
Meta-analysis

ABSTRACT

Background: It has been hypothesised that the ratio of length between the second and fourth fingers (2D:4D), commonly employed as an indicator of foetal sex hormone exposure, may be positively correlated between heterosexual partners.
Aims: As previous evidence has been conflicting, our study aimed to determine whether intra-couple correlations exist for digit ratio variables, and if so, to estimate the size and direction of these effects.
Study design: We present a preregistered (osf.io/6jg8p) correlational study and quantitative meta-analysis of the available literature, and attempted to locate further published and unpublished data (i.e. 'grey literature') by contacting $n = 248$ researchers in the 2D:4D and related fields.
Subjects: $n = 58$ heterosexual dating couples from the UK took part in our empirical study, and the meta-analysis included data from $k = 11$ samples.
Outcome measures: We measured digit ratio for the right hand (R2D:4D), left hand (L2D:4D), and average of both hands (M2D:4D), as well as the right-left-difference ($D_{[R-L]}$).
Results: We found no evidence of significant positive intra-couple correlations in our own data, but a significant (positive) meta-analytic effect size estimate emerged for R2D:4D ($r = 0.072$, $p = 0.014$). The meta-analytic effects for L2D:4D ($r = 0.043$, $p = 0.303$), M2D:4D ($r = 0.070$, $p = 0.225$), and $D_{[R-L]}$ ($r = 0.028$, $p = 0.649$) were all in the same direction but not statistically significant. However, if the sample from Klimek et al. (2014, 2016) were omitted, meta-analysis would also yield a significant positive correlation for M2D:4D ($r = 0.128$, $p = 0.001$).
Conclusions: Although our findings are based on a fairly small range of studies, which themselves provide a relatively small sample of participants, they do imply the intriguing possibility of small effects of positive assortment in relation to characteristics associated with the prenatal hormonal environment.

1. Introduction

Digit ratio (2D,4D) may provide a retrospective indicator of the foetal hormonal environment, with low ratios (i.e. a long ring finger relative to index finger) being thought to signify exposure to high levels of testosterone relative to oestradiol [1–3]. Although questions remain regarding its validity [4–8] (cf. [9]), the measure is commonly employed in correlational studies that attempt to investigate relationships between foetal hormone exposure and sexually differentiated outcomes. Researchers typically examine digit ratios for the right hand (R2D:4D) and left hand (L2D:4D), though some studies report on the average of both hands (M2D:4D). Based on the idea that masculine traits may be expressed to a greater degree on the right (as opposed to the left) side of the body [10], Manning (2002, p. 21–22) [2] suggested that the right-left difference in digit ratio ($D_{[R-L]}$) can serve as an additional proxy for early androgen action. More specifically, low R2D:4D relative to L2D:4D is hypothesised to indicate high levels of foetal testosterone exposure.

Manning (2002, p. 51–52) [2] examined associations between 2D:4D and the wearing of wedding rings in a sample of 79 married couples recruited from adult education classes and social clubs in Liverpool, UK. M2D:4D was lower in the husbands of women who wore wedding rings compared with the husbands of those who did not ($t = 1.89$, $p = 0.03$, one-tailed). However, this finding did not

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https://doi.org/10.1016/j.earlhumdev.2020.105159
Received 2 July 2020; Received in revised form 10 August 2020; Accepted 18 August 2020
Available online 20 August 2020
0378-3782/

generalise to married men's wearing of wedding rings ($t = 0.12$, $p = 0.91$), and was not replicated in a larger study by Voracek [11]. Evidence that 2D:4D is a reliable predictor of attractiveness of the hands is also inconsistent [12,13] (see also Manning & Crone, as cited in [2]). However, the measure may remain relevant in the context of mate selection as it has been shown to correlate with a range of reproductive outcomes including family size [14,15], age at menarche [16–18], lifetime number of sexual partners [19,20], length of the female reproductive period [16], and partner attractiveness [21].

A significant correlation for 2D:4D between romantic partners could imply that assortative mating occurs in relation to characteristics of the foetal hormonal environment or on the morphology of the hands. That is, it would provide evidence that individuals select partners in a non-random manner in which they are more similar to each other than would be predicted by chance (see Kardum et al. [22]). In this example, it appears likely that a significant intra-couple correlation would reflect phenotypic assortment and dissimilarity avoidance for other traits and phenotypes associated with 2D:4D [2,23]. Voracek et al. [23] suggested that candidate traits may include social and courtship-related behavioural displays, body mass index (BMI), waist-to-hip ratio (WHR), waist-to-chest ratio (WCR), facial shape, fluctuating asymmetry, personality, sensation-seeking, sociosexuality, and psychological masculinity-femininity.

Summary information for studies reporting on intra-couple correlations for digit ratio variables is presented in Table 1. The first such investigation [24] reported no effect for the average of right- and left-hand distal finger extent (broadly akin to 2D:4D [25]). However, as noted by Voracek et al. [23], these findings may be uninformative because they relate to distal finger extent rather than 2D:4D, and, perhaps more importantly, to a population for which arranged marriage practices are common. The latter is of consequence because such procedures could disrupt natural mate selection processes.

The most compelling evidence for an intra-couple correlation for 2D:4D comes from a study of 239 Austrian married couples [23], all of whom had reproduced, which reported significant positive correlations for R2D:4D, L2D:4D, and M2D:4D (though not $D_{[R-L]}$). Similar results were observed for participants of parental age and grandparental age, though not all effects were statistically significant for these subgroup analyses. However, a recent study by Kalichman et al. [26,27] reported no significant intra-couple correlations for R2D:4D or L2D:4D in a similar sized Chuvashian sample. Nevertheless, it is worth noting that this study measured 2D:4D from radiographs, whereas others used direct measures [15,24,28], scans [29], photocopies [23,30], or a combination of direct measures and photocopies [31]. Furthermore, this sample was selected due to genetic and environmental homogeneity [26,32], factors which could restrict the degree of assortative mating possible within a population. Taken together, the available literature suggests that if there are intra-couple correlations for digit ratio variables, they are in the positive direction and of small magnitude.

2. Empirical study

2.1. Empirical study material and methods

Our empirical study examined 2D:4D within a sample of heterosexual dating couples from the UK, and took place within the context of a larger study examining assortative mating in relation to autistic traits, empathizing, and systemizing. We pre-registered our analysis plan on the Open Science Framework (osf.io/6jg8p), and predicted positive intra-couple correlations for R2D:4D, L2D:4D, and M2D:4D, and no intra-couple correlation for $D_{[R-L]}$. Effects are considered statistically significant at $p < 0.050$ (two-tailed), and effect sizes are interpreted in accordance to the criteria specified by Cohen [33] (i.e. small, $d = 0.20$, $r = 0.10$; medium $d = 0.50$, $r = 0.30$; large $d = 0.80$, $r = 0.50$).

2.2. Participants

Fifty eight heterosexual dating couples were recruited from the UK, and took part in exchange for high street shopping vouchers. Females were aged between 18 and 75 ($M = 33.76$, $SD = 15.56$), and males were aged between 19 and 76 ($M = 35.34$, $SD = 15.68$). In accordance with previous findings, partners' ages were very strongly positively correlated, $r(56) = 0.975$, $p < 0.001$, and a paired-samples t-test showed that females were significantly younger than their male partners, $t(57) = -3.457$, $p = 0.001$, $d = -0.452$.

2.3. Apparatus/materials

Participants were asked to complete a short questionnaire to record their age, sex, and relationship duration, and requested not to confer. Digital Vernier callipers (measuring to 0.01 mm) were used to measure the second and fourth fingers of each hand. Participants also completed several measures relating to autism and autistic traits (see pre-registration document for further details: osf.io/6jg8p).

2.4. Design and procedure

We used a correlational design to determine whether each of the digit ratio variables (R2D:4D, L2D:4D, M2D:4D, $D_{[R-L]}$) were correlated within couples. Each couple attended a lab session together in which study information was provided and informed consent was recorded. After the participants reported their demographic information, trained Research Assistants used digital Vernier callipers to measure their finger lengths in the following order: R2D, R4D, L2D, L4D. They were then debriefed on completion of the study. Each couple was provided with a £10.00 Amazon voucher, and made aware that they would receive this even if they or their partner (or both) did not complete the study. Ethical approval was obtained from the Department of Psychology Research Ethics Committee, Birmingham City University (approval number: 172.17), and all procedures were conducted in accordance with the Declaration of Helsinki. Statistical analyses were conducted using SPSS version 26.

2.5. Empirical study results

Intra-class correlation coefficients (single measures, absolute agreement) were conducted to determine the repeatability of the two sets of digit ratio measures. Each test was highly statistically significant, though the repeatability of measurements was somewhat lower than typically reported in the literature: R2D:4D, $ICC(115, 115) = 0.663$, $p < 0.001$; L2D:4D, $ICC(115, 115) = 0.820$, $p < 0.001$; M2D:4D, $ICC(115, 115) = 0.724$, $p < 0.001$; $D_{[R-L]}$, $ICC(115, 115) = 0.764$, $p < 0.001$. The two sets of measurements were averaged, with the resulting variables being used in all subsequent analyses.

M2D:4D was marginally lower in males than females, and the effects for R2D:4D, L2D:4D, and $D_{[R-L]}$ were not statistically significant (Table 2). Pearson's correlations determined that there was no significant intra-couple correlation for R2D:4D $r(56) = -0.124$, $p = 0.352$, L2D:4D $r(56) = -0.183$, $p = 0.170$, or M2D:4D, $r(56) = -0.016$, $p = 0.907$, and that there was a significant negative correlation for $D_{[R-L]}$, $r(56) = -0.321$, $p = 0.014$. However, this last effect appeared to be driven by a single outlier (Cook's distance = 1.195 [female $D_{[R-L]} = 0.158$; male $D_{[R-L]} = -0.292$]), removal of which resulted in a non-significant correlation, $r(55) = -0.099$, $p = 0.465$ (Fig. 1) (the sex difference for $D_{[R-L]}$ remained non-significant when this outlier was excluded from the analysis: male $M = -0.002$ [$SD = 0.039$]; female $M = -0.011$ [$SD = 0.057$], $t[56] = -0.885$, $p = 0.380$, $d = -0.124$). For completeness and consistency with other studies, however, the effect size entered into the subsequent meta-analysis for $D_{[R-L]}$ was that for which the outlier was included.

Table 1
Summary of previously reported intra-couple correlations for digit ratio variables.

Digit ratio	Authors	Year	Journal	Country	Population	Measurement	*n*	*r*	*p*
R2D:4D	Manning et al.	2000	*Evolution and Human Behavior*	UK	Merseyside couples	Direct (Vernier callipers)	90	0.152	0.15
	Manning et al.	2001	*Developmental Medicine and Child Neurology*	UK	Parents of autistic children	Photocopies	75	0.01	n.s.
	Voracek et al.	2007	*Journal of Biosocial Science*	Austria	Married couples with at least one shared child (all participants)	Photocopies	239	0.198	< 0.01
					Parental generation subsample		189	0.189	< 0.01
					Grandparental generation subsample		50	0.237	< 0.10
	Hauth et al.	2014	*Autism Research*	Netherlands	Parents with at least one shared child	Direct (measuring tape)	253	0.08	0.22
	Richards et al.	2017	*Early Human Development*	UK	General Welsh population	Scans	23	−0.306	0.155
	Kalichman et al.	2019	*Annals of Human Biology*	Russia	Population-based sample of Chuvashians	Radiographs[1]	297	−0.012	0.958
	Kalichman et al.	2020	*Collegium Antropologicum*	Russia	Population-based sample of Chuvashians	Radiographs (finger ratio)	290	0.050	0.398
						Radiographs (ray ratio)	278	−0.013	0.981
L2D:4D	Manning et al.	2000	*Evolution and Human Behavior*	UK	Merseyside couples	Direct (Vernier callipers)	90	0.136	0.21
	Manning et al.	2001	*Developmetnal Medicine and Child Neurology*	UK	Parents of autistic children	Photocopies	82	0.16	n.s.
	Voracek et al.	2007	*Journal of Biosocial Science*	Austria	Married couples with at least one shared child (all participants)	Photocopies	239	0.189	< 0.01
					Parental generation subsample		189	0.141	< 0.10
					Grandparental generation subsample		50	0.338	< 0.05
	Hauth et al.	2014	*Autism Research*	Netherlands	Parents with at least one shared child	Direct (measuring tape)	253	0.07	0.28
	Richards et al.	2017	*Early Human Development*	UK	General Welsh population	Scans	23	−0.156	0.477
	Kalichman et al.	2019	*Annals of Human Biology*	Russia	Population-based sample of Chuvashians	Radiographs[1]	306	0.040	0.501
	Kalichman et al.	2020	*Collegium Antropologicum*	Russia	Population-based sample of Chuvashians	Radiographs (finger ratio)	290	−0.013	0.977
						Radiographs (ray ratio)	290	−0.013	0.977
M2D:4D	Marshall	2000	Unpublished MSc thesis	UK	Liverpool couples/friends and family	Direct (Vernier callipers) and photocopies	10	−0.123	0.841
	Manning	2002	Book	UK	Merseyside couples	Not reported	221	0.15	0.052[2]
	Voracek et al.	2007	*Journal of Biosocial Science*	Austria	Married couples with at least one shared child (all participants)	Photocopies	239	0.242	< 0.001
					Parental generation subsample		189	0.209	< 0.01
					Grandparental generation subsample		50	0.363	< 0.01
	Marshall	2000	Unpublished MSc thesis	UK	Liverpool couples/friends and family	Direct (Vernier callipers) and photocopies	10	0.133	0.821
	Voracek et al.	2007	*Journal of Biosocial Science*	Austria	Married couples with at least one shared child (all participants)	Photocopies	239	−0.009	n.s.
					Parental generation subsample		189	−0.015	n.s
					Grandparental generation subsample		50	−0.013	n.s
Average distal finger extent	Ramesh & Murty	1977	*Annals of Human Biology*	India	Endogamous Reddy community of Nalgonda District	Direct (graph paper)	148	0.038	n.s

[1] The spousal correlations presented in Kalichman et al. (2019) are reported again in Kalichman et al. (2020) and relate to visual classification of hand types (i.e. 2D < 4D, 2D = 4D or 2D > 4D).
[2] The p value originally reported by Manning (2002) was 0.026 (one-tailed).

Table 2
Descriptive statistics and sex differences for digit ratio variables.

Digit ratio	Males			Females			Sex difference			
	n	*M*	*SD*	*n*	*M*	*SD*	*t*	df	*p*	*d*
R2D:4D	58	0.993	0.039	58	1.004	0.044	1.316	57	0.193	0.176
L2D:4D	58	1.000	0.048	58	1.012	0.040	1.286	57	0.204	0.177
M2D:4D	58	0.997	0.034	58	1.008	0.029	1.872	57	0.066	0.244
$D_{[R-L]}$	58	−0.007	0.054	58	−0.008	0.061	−0.046	57	0.964	−0.011

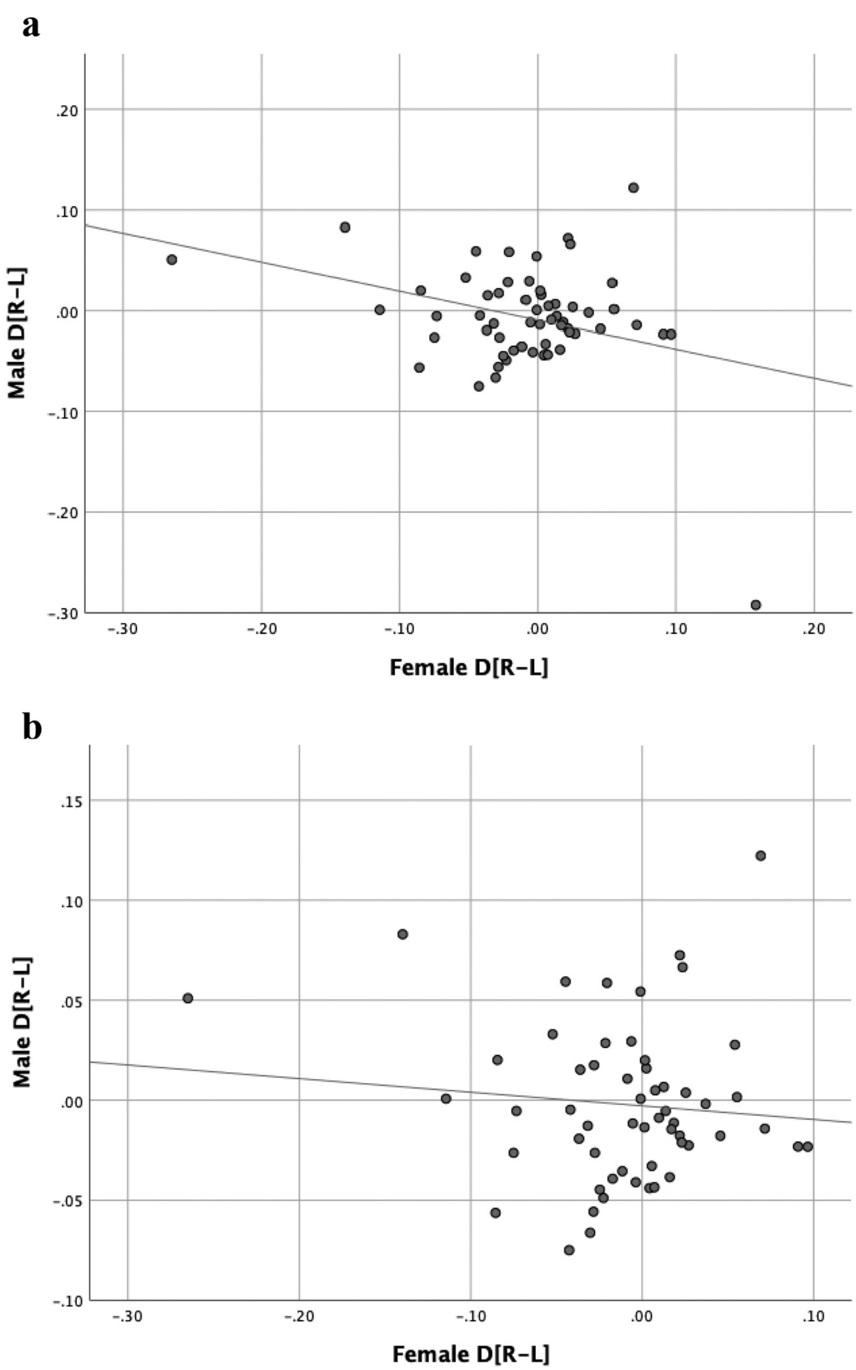

Fig. 1. Intra-couple correlation for $D_{[R-L]}$.
Note. Fig. 1a presents the intra-couple correlation for $D_{[R-L]}$ with all datapoints included ($r = -0.321$, $p = 0.014$); Fig. 1b presents the same correlation with one outlier removed (the outlier in question is present in the bottom-right-hand corner of Fig. 1a ($r = -0.099$, $p = 0.465$).

3. Meta-analysis

3.1. Meta-analysis method

We began conducting literature searches relating to 2D:4D and assortative mating. However, it quickly became apparent that this strategy would not identify published studies reporting data from couples for purposes other than the investigation of assortative mating. For instance, a search of the database of 2D:4D studies maintained by Fink and Manning [34] (n = 912 as of 02.07.2020) revealed only one article with 'assortative' [23] and one article with 'couple' [35] in the title. To identify as many relevant datasets as possible, we therefore scanned each of the article titles included in this database, checked the reference lists of papers we had already identified as relevant, and contacted n = 248 researchers in the 2D:4D and related fields to enquire about unpublished studies. This processes identified studies published by Cousins et al. [35], Gobernado et al. [36], and Klimek et al. [14,37], for which 2D:4D data had been collected from couples but intra-couple correlations were not reported in the published articles. We contacted authors of these studies to request access to the data (or for them to calculate the relevant effect sizes and share them with us), and included each within the meta-analysis other than Cousins et al. [35] (data for which we were unable to locate).

We conducted random-effects meta-analyses using the R package metafor [38] to compute weighted average effect sizes for intra-couple correlations for R2D:4D (k = 11, n = 1566), L2D:4D (k = 11, n = 1573), M2D:4D (k = 9, n = 1031), and $D_{[R-L]}$ (k = 8, n = 810). We chose to use random-effects rather than fixed-effects meta-analysis due to the plausibility of there being true effect heterogeneity for assortative mating in relation to 2D:4D (or, more likely, in relation to other variables that are themselves associated with 2D:4D), and also so that the meta-analytic findings may be generalisable over and above the available and retrievable set of primary study data. To correct for bias, we transformed r values to z, performed the meta-analyses on z, and then converted the outcomes back to r for readability [39]. We report heterogeneity in terms of I^2, and computed Cochran's Q to formally test for the presence of heterogeneity. Additionally, we conducted sensitivity analyses using the leave-one out-procedure to explore the possibility of there being particularly influential studies, and to determine the effects on the overall meta-analytic model if any one sample were to be excluded.

3.2. Meta-analysis results

We conducted random-effects meta-analyses for the intra-couple correlations for R2D:4D, L2D:4D, M2D:4D, and $D_{[R-L]}$; summary statistics are presented in Table 3 and forest plots are presented in Fig. 2. For R2D:4D, there was a significant positive correlation (r = 0.072, p = 0.014) and no significant heterogeneity. The leave-one-out procedure determined that the exclusion of one sample (the parental generation sample of Voracek et al. 2007 [23]) would yield a model just shy of the $p < 0.050$ significance threshold (r = 0.053 [95% CI = 0.000, 0.106], z = 0.053 [95% CI = −0.0003, 0.107], p = 0.051). For L2D:4D, the effect size estimate was not statistically significant (r = 0.043, p = 0.303), although significant heterogeneity was detected. Similar results were observed for M2D:4D, with a non-significant effect size estimate (r = 0.070, p = 0.225) and significant heterogeneity. However, in this case, removal of the study by Klimek et al. [14,37] resulted in a significant effect (r = 0.128 [95% CI = 0.055, 0.200], z = 0.129 [95% CI = 0.055, 0.203], p = 0.001). Finally, no correlation was observed for $D_{[R-L]}$ (r = 0.028, p = 0.649), although there was significant heterogeneity.

4. Discussion

The current study presents a review and meta-analysis of studies that have examined intra-couple correlations for digit ratio variables, as well as some new empirical data. In accordance with our preregistration plan (osf.io/6jg8p), we hypothesised that there would be positive intra-couple correlations for R2D:4D, L2D:4D, and M2D:4D, but no intra-couple correlation for $D_{[R-L]}$. We did not observe significant positive correlations in our empirical study but meta-analysis revealed a significant (positive) effect size estimate for R2D:4D (r = 0.072, p = 0.014). Effect size estimates for L2D:4D (r = 0.043, p = 0.303), M2D:4D (r = 0.070, p = 0.225), and $D_{[R-L]}$ (r = 0.028, p = 0.649) were all in the same direction but not statistically significant. Interestingly, omission of one sample [14,37] (n = 219) resulted in a significant positive correlation for M2D:4D (r = 0.128, p = 0.001). Although this pattern of results may suggest that humans assort in a non-random fashion in regard to traits associated with variations in prenatal sex hormone exposure, such effects appear to be extremely small in magnitude, and further studies will be required to determine more reliable estimates.

As the removal of a single sample [14,37] would yield a statistically significant effect size estimate for M2D:4D, a closer look at this study is warranted. The sample (male data presented in [14]; female data presented in [37]) came from the Mogielica Human Ecology Study, a longstanding project examining the ecology, hormones, and behaviour of a rural community in southern Poland. Importantly, natural fertility (i.e. relatively little use of modern contraception) is typical in this population. Additionally, the couples included here were all married, which indicates that the sample is comprised of stable long-term pair-bonds of relatively high fecundity and fertility. However, though these observations would appear to increase the likelihood of assortative mating patterns being detectable, it is also crucial to note that, although specific data on marriage practices were not collected, some marriages were essentially arranged, people (especially women) in this sample do not usually travel far, and people from this area of Poland tend to marry others from within their own small village or from other nearby villages (G. Jasienska, Personal communication). The pool of potential mates for this sample was therefore much smaller than typically found in cities, a factor that would likely attenuate observable effects of positive assortment.

The effect sizes observed here are very small in terms of the amount of variance explained. However, although intra-couple correlations for variables such as educational attainment (r = 0.412 [40]) may be fairly strong, those for personality variables (typically $r < 0.30$ [41]) and bodily parameters more conspicuous than digit ratios (e.g. height, r = 0.201; BMI, r = 0.228 [40]) tend to be small-to-moderate in size. Furthermore, it should not be forgotten that the cumulative nature of evolutionary processes means that effects of seemingly trivial magnitude can lead to very large changes in phenotype when considered across a large enough timescale [25,42].

It should be noted that the effect sizes for assortative mating in regard to 2D:4D could differ across the studies included in our meta-analysis because the samples varied in some key aspects. For instance, whereas the new empirical study presented here includes dating couples (though some were married), others examined only married couples [14,37] or those with at least one shared child [23,28–30]. Additionally, two samples [28,30] related specifically to parents of autistic children, another [36] to people experiencing fertility problems, and the studies by Klimek et al. [14,37] and Kalichman et al. [26,27] came from geographical regions with strong endogamy systems. With these observations in mind, it may therefore be useful for future studies to examine samples that are fully representative of the general population and to determine whether the magnitude of assortative mating in relation to 2D:4D differs between short-term and long-term pairings.

It has previously been suggested that intra-couple correlations for 2D:4D variables are unlikely to reflect mate selection based on digit ratio itself, but rather reflect phenotypic assortment and/or dissimilarity avoidance of traits and phenotypes associated with 2D:4D [2,23]. Although Voracek et al. [23] suggested several candidate traits

Table 3
Summary statistics for random-effects meta-analyses of intra-couple correlations for digit ratio variables.

Digit ratio	Study	*n*	*r*	*Vr*	*z*	*Vz*	Effect size estimate			Heterogeneity				
							r (95% CI)	*z* (95% CI)	*p*	Q	df	*p*	τ	I^2
R2D:4D	Manning et al. (2000)	90	0.152	0.0107	0.1532	0.0115	0.072 (0.014, 0.128)	0.072 (0.015, 0.129)	0.014	14.411	10	0.155	0.040	17.31%
	Manning et al. (2001)	75	0.010	0.0135	0.0100	0.0139								
	Voracek et al. (2007a)	189	0.189	0.0049	0.1913	0.0054								
	Voracek et al. (2007b)	50	0.237	0.0182	0.2416	0.0213								
	Hauth et al. (2014a)	165	0.140	0.0059	0.1409	0.0062								
	Hauth et al. (2014b)	98	0.185	0.0096	0.1872	0.0105								
	Klimek et al. (2014, 2016)	219	−0.013	0.0046	−0.0130	0.0046								
	Richards et al. (2017)	23	−0.306	0.0373	−0.3161	0.0500								
	Gobernado et al. (2019)	309	0.024	0.0032	0.0240	0.0033								
	Kalichman et al. (2020)	290	0.050	0.0034	0.0500	0.0035								
	Richards et al. (2020)	58	−0.124	0.0170	−0.1250	0.0182								
L2D:4D	Manning et al. (2000)	90	0.136	0.0108	0.1368	0.0115	0.043 (−0.039, 0.124)	0.043 (−0.039, 0.124)	0.303	22.607	10	0.012	0.098	56.28%
	Manning et al. (2001)	82	0.160	0.0117	0.1614	0.0127								
	Voracek et al. (2007a)	189	0.141	0.0051	0.1419	0.0054								
	Voracek et al. (2007b)	50	0.338	0.0160	0.3518	0.0213								
	Hauth et al. (2014a)	165	0.116	0.0059	0.1165	0.0062								
	Hauth et al. (2014b)	98	−0.138	0.0099	−0.1389	0.0105								
	Klimek et al. (2014, 2016)	219	−0.107	0.0045	−0.1074	0.0046								
	Richards et al. (2017)	23	−0.156	0.0433	−0.1573	0.0500								
	Gobernado et al. (2019)	309	0.099	0.0032	0.0993	0.0033								
	Kalichman et al. (2020)	290	−0.013	0.0035	−0.0130	0.0035								
	Richards et al. (2020)	58	−0.183	0.0164	−0.1851	0.0182								
M2D:4D	Marshall (2000)	10	−0.123	0.1078	−0.1236	0.1429	0.070 (−0.043, 0.182)	0.070 (−0.043, 0.184)	0.225	22.243	8	0.005	0.129	63.30%
	Manning (2002)	221	0.150	0.0043	0.1511	0.0046								
	Hauth et al. (2014a)	163	0.119	0.0060	0.1196	0.0063								
	Hauth et al. (2014b)	98	0.007	0.0103	0.0070	0.0105								
	Klimek et al. (2014, 2016)	219	−0.132	0.0044	−0.1328	0.0046								
	Richards et al. (2017)	23	−0.255	0.0397	−0.2608	0.0500								
	Voracek et al. (2007a)	189	0.209	0.0049	0.2121	0.0054								
	Voracek et al. (2007b)	50	0.363	0.0154	0.3803	0.0213								
	Richards et al. (2020)	58	−0.016	0.0175	−0.0160	0.0182								
$D_{[R-L]}$	Marshall (2000)	10	0.133	0.1072	0.1338	0.1429	0.028 (−0.094, 0.150)	0.029 (−0.094, 0.151)	0.649	14.807	7	0.039	0.127	59.17%
	Voracek et al. (2007a)	189	−0.015	0.0053	−0.0150	0.0054								
	Voracek et al. (2007b)	50	−0.013	0.0204	−0.0130	0.0213								
	Hauth et al. (2014a)	163	0.187	0.0057	0.1892	0.0063								
	Hauth et al. (2014b)	98	0.190	0.0096	0.1923	0.0105								
	Klimek et al. (2014, 2016)	219	0.071	0.0045	0.0711	0.0046								
	Richards et al. (2017)	23	−0.128	0.0440	−0.1287	0.0500								
	Richards et al. (2020)	58	−0.099	0.0175	−0.0993	0.0185								

(social and courtship-related behavioural displays, BMI, WHR, WCR, facial shape, fluctuating asymmetry, personality, sensation-seeking, sociosexuality, and psychological masculinity-femininity), relatively little research has since investigated these possibilities. However, one study of particular interest [21] provided evidence of a pattern of cross-trait assortment involving male 2D:4D and female secondary sexual characteristics. More specifically, the study showed that males with low (i.e. male-typical) R2D:4D and L2D:4D values tended to be partnered with females with low WHRs as well as a combination of relatively narrow waist and large breasts. Although these findings come from a fairly small study ($n = 50$ couples), they do imply that sexual selection processes could be implicated.

As mentioned above, Voracek et al. [23] suggested that facial shape could be a mediator of the intra-couple correlation observed for 2D:4D. This may be of particular relevance as it has been noted that people typically find self-resembling faces attractive [43,44], and that this effect is modulated by fluctuations in sex hormone concentrations observed in females across the menstrual cycle [45]. It is also noteworthy that perinatal testosterone levels measured from umbilical cord blood have been shown to be a strong predictor of facial masculinity in young adulthood [46]. However, as many relevant variables such as sexual dimorphism of the face, masculine-typical behaviour, facial symmetry, and facial attractiveness are likely to be intercorrelated, it is difficult to state with any certainty which if any (or potentially all) of these are relevant to explaining the positive assortment that is reported here in regard to digit ratio.

Our current work has some limitations that should be acknowledged. Firstly, the repeatability estimates for the 2D:4D measurement in our empirical study were fairly low. A possible reason for this is that finger lengths were recorded by several different Research Assistants (although it should be noted that they had all been trained in the use of Vernier callipers by the same researcher). Additionally, as finger lengths were measured directly from participants' hands (i.e. as opposed to being measured from photocopies/scans), the Research Assistants were not blinded to which individuals shared relationships. Although this could potentially lead to biased 2D:4D estimates, this appears unlikely because the Research Assistants only measured participants' finger lengths and did not specifically calculate their 2D:4D ratios. Furthermore, although our empirical study is useful in that it contributed more data to the meta-analysis, it would be of little benefit

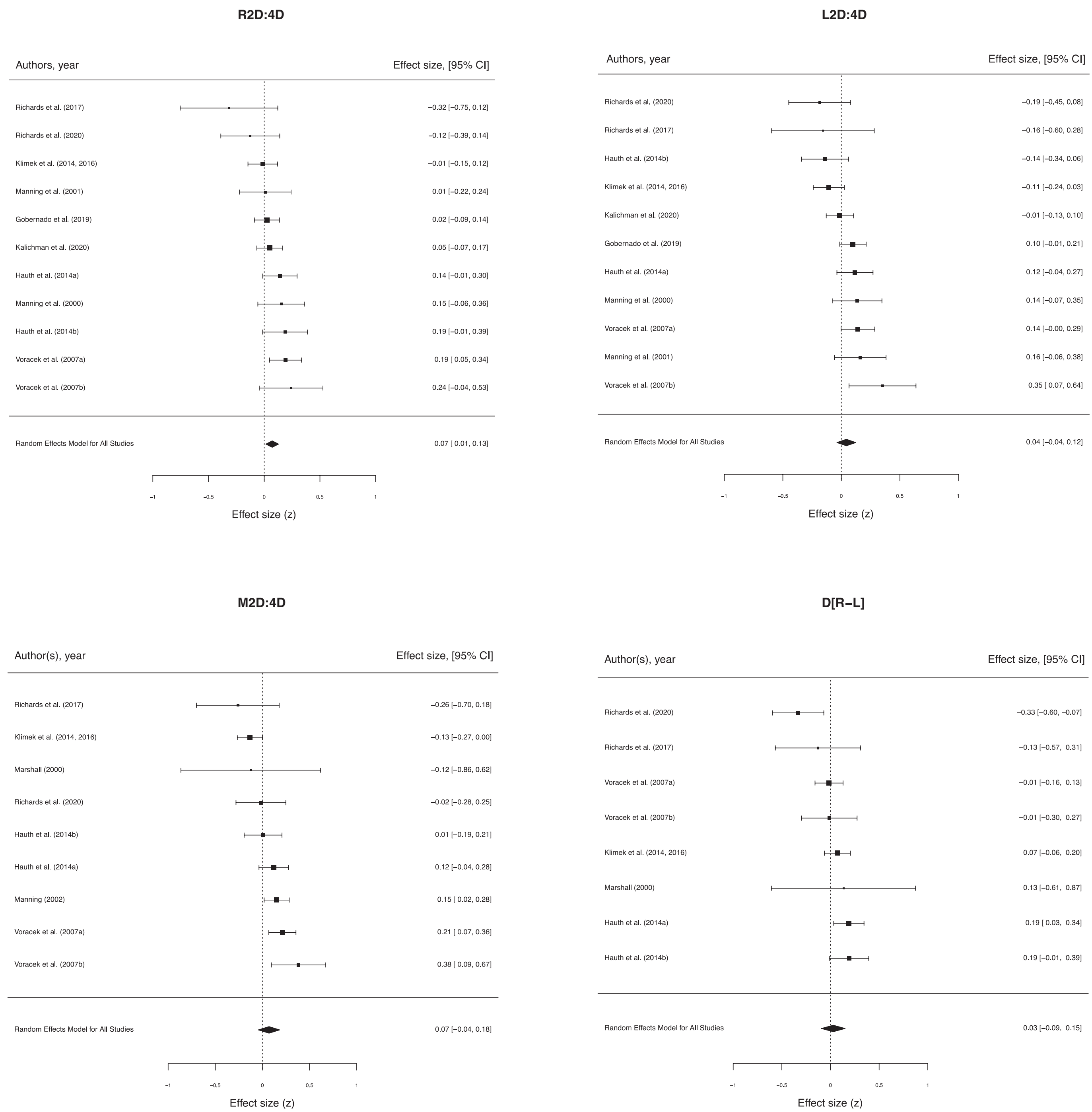

Fig. 2. Forest plots displaying intra-couple correlations for digit ratio variables.
Note. Hauth et al. (2004a) relates to a sample of parents of autistic children whereas Hauth et al. (2004b) relates to a sample of parents of typically developing children; Voracek et al. (2007a) relates to a sample of couples from the parental generation whereas Voracek et al. (2007b) relates to a sample of couples from the grandparental generation.

on its own due to being considerably underpowered to detect effects of such small magnitude. Based on the effect sizes observed in our meta-analysis (R2D:4D, $r = 0.072$; L2D:4D, $r = 0.043$; M2D:4D, $r = 0.070$; $D_{[R-L]}$, $r = 0.028$), power calculations conducting using G*Power 3.1 [47,48] determined that the following sample sizes would be required to observe statistically significant bivariate correlations ($p < 0.050$, two-tailed) with 80% power: R2D:4D ($n = 1511$); L2D:4D ($n = 4242$); M2D:4D ($n = 1599$); $D_{[R-L]}$ (n = 10,010). As the study with the biggest sample within our meta-analysis ($n = 309$ couples) [36] was still too small to detect even the largest of these effects with sufficient power, it is therefore unsurprising that the majority of individual studies contributing data to this area have not reported statistically significant effects.

Another limitation of our study is that there were relatively few samples included in the meta-analyses (R2D:4D, k = 11; L2D:4D, k = 11; M2D:4D, k = 9; $D_{[R-L]}$, k = 8) and the total meta-analytic sample size was not overly large. As statistically significant levels of heterogeneity were observed for L2D:4D, M2D:4D, and $D_{[R-L]}$, a larger number of samples would warrant the use of meta-regression to examine potential moderators. For instance, it would be interesting to know whether the method used to measure digit ratios (e.g. direct vs. indirect; [49]) and/or the samples examined (e.g. clinically-derived or general population) could explain some of the heterogeneity in effect size.

5. Conclusion

Taken together, the current findings show that digit ratio variables may be positively correlated within heterosexual couples, though only the meta-analytic effect size estimate for R2D:4D was statistically significant when all relevant datasets were included. Although such positive intra-couple correlations could imply that people assort non-randomly based on their digit ratios, we consider this implausible; instead, like others [2,23], we suggest that these effects are mediated by assortative mating in regard to other physical and/or behavioural characteristics that are themselves associated with digit ratios. The effects observed in our meta-analysis may be very small, but are of theoretical interest regarding mate selection processes in humans. Such small effect sizes also suggest that studies utilising 2D:4D as a proxy measure of prenatal hormone exposure may need to employ very large sample sizes in order to be of any practical utility.

Funding

This research was supported by a Birmingham City University Small Development Grant (ML/ZM/GP; Ref: SDG 17-18-1.2) awarded to JG. SBC was funded by the Autism Research Trust, the Wellcome Trust, and the NIHR Biomedical Research Centre in Cambridge, during the period of this work. SBC also received funding from the Innovative Medicines Initiative 2 Joint Undertaking (JU) under grant agreement No 777394. The funders played no role in the study design, collection, analysis and interpretation of data, writing of the report, or the decision to submit the article for publication.

Data statement

The datasets are available on the Open Science Framework page for the study rather than as supplementary materials (https://osf.io/38ymp).

CRediT authorship contribution statement

GR: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Visualization; Writing - original draft.

SBC: Conceptualization; Funding acquisition; Writing - review & editing.

TvS: Formal analysis; Software; Visualization; Writing - review & editing.

JG: Conceptualization; Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Writing - review & editing.

Acknowledgements

The authors would like to thank each of the Research Assistants who helped us collect data for our empirical study, as well as the following researchers for sharing data with us for inclusion in our meta-analysis: Dr. José Schneider-Fontán and Prof Julio Gobernado (Gobernado et al., 2019 [36]); Dr. Nanda Lambregts-Rommelse (Hauth et al., 2014 [28]); Dr. Magdalena Klimek, Prof Grazyna Jasienska, and Dr. Andrzej Galbarczyk (Klimek et al., 2014 [14]; Klimek et al., 2016 [37]); we would also like to thank Prof John Manning for sharing with us the unpublished MSc thesis of Marshall (2000) [31].

Declaration of competing interest

None declared.

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