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ORIGINAL ARTICLE

Associations Between Handgrip Strength, Body Size, Digit Ratio, and Fluctuating Asymmetry in Kocha-Rava Young Adult Males of Alipurduar District, West Bengal, India

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ABSTRACT

This study examined the association between total handgrip strength (THGS) and morphological markers including body mass index (BMI), height, digit ratio (2D:4D), and relative fluctuating asymmetry (RFAD) in digits among 309 males aged 22–30 years from the Kocha-Rava community in India. Anthropometric measurements and digit lengths were collected following standard protocols, and THGS was assessed using a digital dynamometer. Partial correlations controlling for age showed significant positive associations between THGS and weight, height, and BMI, while 2D:4D ratios showed no significant relationship. Notably, RFAD in the 2nd digit showed a significant negative correlation with THGS (ρ = –0.389, p = 0.008). Regression analysis confirmed weight as the strongest predictor of THGS, and one-way ANOVA revealed significant differences in THGS across BMI categories prescribed by WHO and 2nd digit RFAD quartile groups. These findings suggest that while body size strongly predicts muscular strength, digit asymmetry may also reflect underlying developmental instability associated with reduced grip strength.

KEYWORDS

• Grip Strength • Anthropometry • Fluctuating Asymmetry • Digit Ratio

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INTRODUCTION

From years of research, hand grip strength (HGS) has been understood to be an indispensable biomarker of overall health, ranging from bone density to cognitive function (Cooper, *et al.*, 2011). Decreased HGS, controlling for age, has also been associated with increased risk of mortality (Oksuzyan, *et al.*, 2017), poorer cognitive function among older adults (Kobayashi-Cuya, *et al.*, 2018) and increased BMI above the normal cut-offs (Moirangmayum, *et al.*, 2024). HGS has also been reported to be increased among females with a lower digit ratio (2D:4D) in challenging situations (Kociuba, *et al.*, 2019) indicating some probable association between grip strength and foetal androgen exposure. HGS may also be associated with developmental stability throughout life (Kuh, *et al.*, 2019) since stronger grip strength has been reported to be associated with heavier birth weight, being able to walk on time during infancy among men. Fluctuating asymmetry (FA) in paired traits, another potential biomarker for developmental instability (Thornhill & Møller, 1997) seems not to be as explored when it comes to the relationship between FA and HGS, especially of FA in digit lengths. It is certainly a possibility that all three potential markers of developmental instability, i.e., digit ratio, hand grip strength, and fluctuating asymmetry in digits, may share some relationship if they are, in fact, symptoms of a much deeper homeostasis or its lack thereof, during development. DR is considered to be fixed during early development, particularly after the third trimester, and does not significantly change with age (Manning, *et al.*, 2014), while HGS increases up to 25 years of age and declines after 30 in men (McGrath, *et al.*, 2020), and FA declines into early adulthood and stays relatively stable until senescence (Palestis & Trivers, 2016) in men. This necessitates that any investigation into the relationship between the three has to be controlled for age.

Whereas digit ratio has been the subject of probably hundreds of studies by now, fluctuating asymmetry in digit lengths is relatively unexplored. Although asymmetry in digit ratio has been linked with higher incidences of hospitalisations and severity of symptoms during COVID-19 (Kasielska-Trojan, *et al.*, 2022), definitive understanding of the nature of morbidities associated with FA in digit dimensions is little. This study aims to fill that research gap by examining the relationship between fluctuating asymmetry, digit ratio and grip strength among young adult men. The objectives of the study are stated below:

- To determine if there is any association between HGS and DR, FA, height and BMI, controlling for age.
- To construct regression models, if the aforesaid variables display any significant correlation with HGS.
- To find out if there are any differences in HGS between the various categories of BMI.

METHODS

For this cross-sectional and correlational study, 309 male participants of the Kocha-Rava community were randomly sampled from three blocks in the Alipurduar district in the north of West Bengal, India. Individuals with upper limb amputations were excluded, and the age of the sampled participants was in the early middle adult age range of 22-30. Since 22 years is usually considered to be post-pubertal in men and no decline in HGS is expected under 30 years of age, the age range was deemed suitable to examine the relationship between the already mentioned variables with minimal noise due to changes in age.

The height of all participants was measured using a stadiometer and recorded in centimetres (cm) up to one decimal place, while body weight was measured with a digital weighing scale and recorded in kilograms (kg). Grip strength of both hands was measured using a digital dynamometer for 3-6 seconds in kilograms (kg), with the highest value being recorded. The measurement protocol followed the guidelines established by the American Society of Hand Therapists (ASHT). Participants were seated with the shoulder adducted and in a neutral rotation, the elbow flexed at 90°, and both the forearm and wrist in a neutral position (Trampisch, *et al.*, 2012). Digit lengths of both hands were measured from the palmar proximal crease to the fingertip using a digital Vernier calliper and recorded in millimetres (mm) up to two decimal places (Mayhew, *et al.*, 2007). All of the anthropometric measurements used in the study were taken on two separate occasions. The intra-observer technical error of measurement (%TEM) was approximately 0.75%, which is within the acceptable range (Goto & Mascie-Taylor, 2007).

BMI was calculated using the formula:

BMI = (*Weight (in Kg)*)/(*Height*^{2} (*in m*^{2}) and categorised according to the WHO Asia Pacific standard, where values < 18.5 Kg/m^2 = underweight, 18.5 – 22.9 Kg/m^2 = normal, 23.0 – 24.9 Kg/m^2 = overweight and ≥ 25.0 Kg/m^2. Digit ratio (2D:4D) was calculated by simply dividing the length of the 2nd digit by the length of the 4th digit on either hand to derive left digit ratio (L-2D:4D) and right digit ratio (R-2D:4D). Relative fluctuating asymmetry (RFAn, where n is the digit number or n = D1, D2, ..., D5) of the digits was calculated by dividing the absolute difference between the lengths of the same digits on either hand with the average length of the same (Voracek, 2009). The following formula may help elucidate the process:

$$RFAn= |(l - r)|/\{((l + r))/2\}$$

Total hand grip strength (THGS) was derived by adding the grip strength of either hand.

For data analysis, all variables were first checked for normality to determine the appropriate tests necessary to examine the relationship between the variables. HGS and height, weight, BMI, L-2D:4D, R-2D:4D, and RFA of all digits were then correlated partially, controlling for age, and linear regression models were derived for significant correlations after testing for the assumptions of the residual statistics necessary for performing linear regression. Significantly correlated RFAn of the digits are then categorised into quartiles and labelled as Grade 1, Grade 2, Grade 3 and Grade 4, in terms of increasing fluctuating asymmetry. Lastly, one-way ANOVA was performed with Fisher's Least Significant Difference (LDS) post-hoc test, after meeting the assumptions, to find out the differences, if any, in HGS between the various categories of BMI and RFA. All analyses were performed in the SPSS 26.0 package by IBM.

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics for the study variables. The total handgrip strength (THGS) showed a mean of 85.44 kg (SD = 13.04), with values ranging from 51.30 kg to 126.50 kg with a relatively low skewness (0.36) and excess kurtosis (0.38). Height and weight have a mean of 163.34 cm (SD = 4.85) and 59.12 kg (SD = 5.34) respectively with minimal skewness and kurtosis as well. BMI showed a mean of 20.88 kg/m² (SD = 2.89), with minimal skewness (0.24) and mesokurtosis (-0.16). In contrast, the RFA variables (RFAD1 to RFAD5) exhibited pronounced positive skewness (ranging from 1.31 to 2.63) and high excess kurtosis (2.17 to 10.48), indicating non-normal distributions with heavy tails. The digit ratios, L-2D:4D and R-2D:4D, showed means of 0.95 (SD = 0.05) and 0.94 (SD = 0.04), respectively. Both exhibited substantial negative skewness (L-2D:4D = -1.17; R-2D:4D = -1.44) and high kurtosis (4.29 and 4.84, respectively), indicating that the distributions are left-skewed and leptokurtic. These findings suggest that while most participants had typical digit ratios, a subset had markedly lower values.

Table 2 shows the Kolmogorov-Smirnov and Shapiro-Wilk tests performed on the variables to determine whether the variables are normally distributed. RFAD1 to RFAD2 are found to be statistically significant at p<0.01 level on both metrices, therefore indicating that the variables are not normally distributed. The rest appear to be normally distributed since they do not show any statistical significance in both tests.

Table 1: Descriptive Statistics of measured and derived variables

Variables	Mean ± SD (n = 309)	Min	Max	Excess Kurtosis	Skewness
THGS (kg)	85.44 ± 13.04	51.30	126.50	00.38	00.36
Height (cm)	163.34 ± 04.85	146.00	178.20	00.49	00.78
Weight (kg)	59.12 ± 05.34	40.30	79.80	- 00.29	00.35
BMI (kg/m2)	20.88 ± 02.89	16.65	29.48	- 00.16	00.24
RFAD 1	0.0357 ± 0.013	0.0003	0.1344	02.17	01.31
RFAD 2	0.0239 ± 0.022	0.0004	0.1439	07.81	02.29

Variables	Mean ± SD (n = 309)	Min	Max	Excess Kurtosis	Skewness
RFAD 3	0.0192 ± 0.018	0.0001	0.1151	05.84	01.92
RFAD 4	0.0213 ± 0.019	0.0001	0.1361	07.50	02.13
RFAD 5	0.0213 ± 0.021	0.0001	0.1457	10.48	02.63
L-2D:4D	00.95 ± 00.05	00.69	01.10	04.29	- 1.17
R-2D:4D	00.94 ± 00.04	00.72	01.07	04.84	- 1.44

Table 2: Normality tests for measured and derived variables

	Kolmogorov-Smirnov			Shapiro-Wilk		
	D-value	df	p-value	W-value	df	p-value
THGS	0.057	309	0.200	0.989	309	0.550
Height	0.034	309	0.671	0.982	309	0.274
Weight	0.048	309	0.989	0.995	309	0.932
BMI	0.074	309	0.184	0.981	309	0.141
RFAD 1	0.103	309	0.008**	0.897	309	<0.001**
RFAD 2	0.117	309	0.001**	0.912	309	<0.001**
RFDA 3	0.181	309	<0.001**	0.820	309	<0.001**
RFAD 4	0.134	309	<0.001**	0.903	309	<0.001**
RFAD 5	0.167	309	<0.001**	0.766	309	<0.001**
L-2D:4D	0.054	309	0.200	0.994	309	0.911
R-2D:4D	0.049	309	0.200	0.992	309	0.784

**significant at p < 0.01

In table 3, partial correlation analyses were conducted to examine the associations between total handgrip strength (THGS) and anthropometric and digit ratio variables, while statistically controlling for age. Significant positive partial correlations were observed between THGS and height (ρ = 0.373, p < 0.001), weight (ρ = 0.466, p < 0.001), and BMI (ρ = 0.343, p < 0.001). These results suggest that, independent of age, individuals with greater body size and mass tend to exhibit higher handgrip strength.

Table 3: Linear partial correlations between TGHS (Total Hand Grip Strength) and the described variables, controlling for age

Variables	ρ XY.Age	p-value
Height	0.373	< 0.001**
Weight	0.466	< 0.001**
BMI	0.343	< 0.001**
L-2D:4D	-0.009	0.927
R-2D:4D	0.147	0.137

**significant at p < 0.01.

In contrast, digit ratio measures were not significantly correlated with THGS after controlling for age.

In table 4, Among the five fluctuating asymmetry variables of the digits, a significant negative partial correlation was observed between THGS and RFAD2 (ρ = –0.389, p = 0.008), indicating that greater asymmetry in the second digit was associated with lower handgrip strength, independent of age.

Table 4: Spearman rank partial correlations between THGS (Total Hand Grip Strength) and the described variables, controlling for age

Variables	ρ XY.Age	p-value
RFAD 1	0.081	0.413
RFAD 2	-0.389	0.008**
RFAD 3	0.046	0.643
RFAD 4	0.066	0.510
RFAD 5	0.040	0.692

**significant at p < 0.01.

To examine the extent to which anthropometric variables and relative digit asymmetry predict total handgrip strength (THGS), four simple linear regression models were constructed (Table 5). All models were statistically significant ($p < 0.01$), though the strength of the associations varied.

Weight emerged as the strongest predictor of THGS ($R = 0.452$, Adjusted $R^2 = 0.206$, $F = 26.168$, $p < 0.001$), explaining approximately 20.6% of the variance in handgrip strength. Height was also a significant predictor ($R = 0.373$, Adjusted $R^2 = 0.139$, $F = 16.152$, $p < 0.001$), as was BMI ($R = 0.325$, Adjusted $R^2 = 0.105$, $F = 12.049$, $p < 0.001$). These findings again indicate that greater body size is generally associated with higher handgrip strength. Interestingly, RFAD2 was found to be negatively associated with THGS ($\beta = -191.749$, $R = 0.367$, Adjusted $R^2 = 0.132$, $F = 6.720$, $p = 0.008$), suggesting that individuals with higher asymmetry in the second digit tend to have lower handgrip strength. The Durbin-Watson statistics for all models ranged from 1.653 to 1.776, indicating no significant autocorrelation in the residuals.

Table 5: Simple linear regression equations between THGS and statistically significant variables

Models	R	Adjusted R2	S.E. of the Estimate	SSR	F-value	p-value	Durbin-Watson Statistic
THGS = - 85.043 + 1.038 (Height)	0.373	0.139	12.16	2441.12	16.152	<0.001**	1.653
THGS = 44.414 + 0.694 (Weight)	0.452	0.206	11.69	3576.01	26.168	<0.001**	1.776
THGS = 53.454 + 1.462 (BMI)	0.325	0.105	12.39	1850.99	12.049	<0.001**	1.764
THGS = 89.490 – 191.749 (RFAD2)	0.367	0.132	12.68	1082.89	06.720	0.008**	1.695

**significant at p < 0.01.

Table 6: One-way ANOVA of THGS between various categories of BMI

	BMI Categories (I)	BMI Categories (J)	Mean Difference (I-J)	S.E.	p-value	95% CI	
						Lower Bound	Upper Bound
Fisher's LSD	Underweight	Normal	- 05.47	04.31	0.207	- 14.02	03.07
		Overweight	- 10.69	05.17	0.041*	- 20.95	- 0.44
		Obese	- 13.38	05.10	0.009**	- 23.50	- 03.25
	Normal	Underweight	05.47	04.31	0.207	- 03.07	14.02
		Overweight	- 05.22	03.64	0.154	- 12.44	01.99
		Obese	- 07.90	03.54	0.028*	- 14.94	- 0.87
	Overweight	Underweight	10.69	05.17	0.041*	0.44	20.95
		Normal	05.22	03.64	0.154	- 01.99	12.44
		Obese	- 02.68	04.55	0.557	- 11.71	06.34
	Obese	Underweight	13.38	05.10	0.009**	03.25	23.50
		Normal	07.90	03.54	0.028*	0.87	14.94
		Overweight	02.68	04.55	0.557	- 06.34	11.71
One- way ANOVA	Between Groups	Sum of Squares			1491.28		
		Mean Square			497.09		
		F-value			03.101		
		df			3		
		p-value			0.029*		
Test of Homoscedasticity	Based on trimmed mean	Levene's Statistic			0.980		
		df			3		
		p-value			0.405		

**significant at p < 0.01, *significant at p < 0.05.

In table 6, a one-way ANOVA was conducted to compare THGS across four BMI categories: Underweight, Normal, Overweight, and Obese. The analysis revealed a statistically significant difference in THGS between at least two BMI groups, F (3, df) = 3.101, p = 0.029, with a mean square of 497.09 and a sum of squares between groups of 1491.28. Levene's test of homogeneity of variances was not significant (p = 0.405), indicating that the assumption of equal variances across groups was met. Post hoc comparisons using Fisher's Least Significant Difference (LSD) test showed the that obese individuals had significantly higher THGS compared to those who are underweight (*Mean Difference* = 13.38, p = 0.009, 95% CI [3.25, 23.50]) and normal (*Mean Difference* = 7.90, p = 0.028, 95% CI [0.87, 14.94]). The overweight individuals also had significantly higher THGS compared to those that are underweight (*Mean Difference* = 10.69, p = 0.041, 95% CI [0.44, 20.95]). These findings suggest that BMI is associated with differences in muscular strength, with higher BMI categories generally demonstrating greater handgrip strength.

In table 7, participants were categorized into four grades of RFAD2 by dividing them into quartiles as stated in the methods section. A one-way ANOVA revealed a statistically significant difference in THGS across RFAD2 categories, F (3, df) = 2.70, p = 0.044, with a between-groups sum of squares of 1328.49 and mean square of 442.83. Levene's test for equality of variances was not significant (p = 0.611), indicating the assumption of homogeneity of variances was met. Post hoc comparisons using Fisher's LSD test showed that individuals with Grade 4 asymmetry (highest asymmetry) had significantly lower THGS compared to those in Grade 1 (*Mean Difference* = –8.79, p = 0.014, 95% CI [–15.79, –1.79]).

Table 7: One-way ANOVA of THGS between various categories of RFAD2

	RFAD2 Categories (I)	RFAD2 Categories (J)	Mean Difference (I-J)	S.E.	p-value	95% CI	
						Lower Bound	Upper Bound
Fisher's LSD	Grade 1	Grade 2	01.45	03.52	0.681	-05.54	08.44
		Grade 3	03.87	03.37	0.253	-02.82	10.56
		Grade 4	08.79	03.52	0.014*	01.79	15.79
	Grade 2	Grade 1	-01.45	03.52	0.681	-08.44	05.54
		Grade 3	02.42	03.64	0.507	-04.79	09.63
		Grade 4	07.34	03.78	0.055	-00.16	14.83
	Grade 3	Grade 1	-03.87	03.37	0.253	-10.56	02.82
		Grade 2	-02.42	03.64	0.507	-09.63	04.79
		Grade 4	04.92	03.63	0.179	-02.29	12.13
	Grade 4	Grade 1	-08.78	03.52	0.014*	-15.79	-01.79
		Grade 2	-07.34	03.78	0.055	-14.83	00.16
		Grade 3	-04.92	03.63	0.179	-12.13	02.29
One- way ANOVA	Between Groups	Sum of Squares	1328.49				
		Mean Square	442.83				
		F-value	2.70				
		df	3				
		p-value	0.044*				
Test of Homoscedasticity	Based on trimmed mean	Levene's Statistic	0.609				
		df	3				
		p-value	0.611				

*significant at p < 0.05.

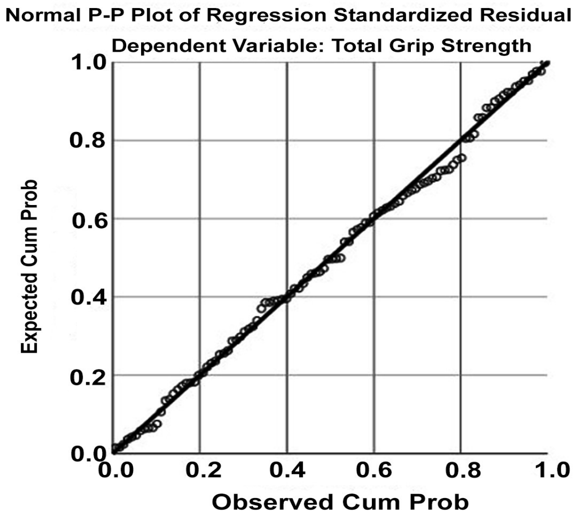

Figure 1: Regression Standardized Residuals of regression between Height and THGS

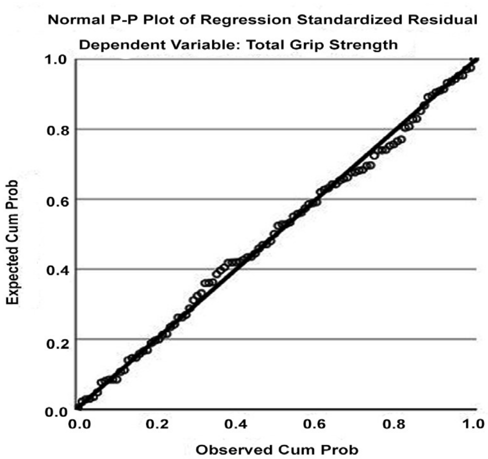

Figure 2: Regression Standardized Residuals of regression between Weight and THGS

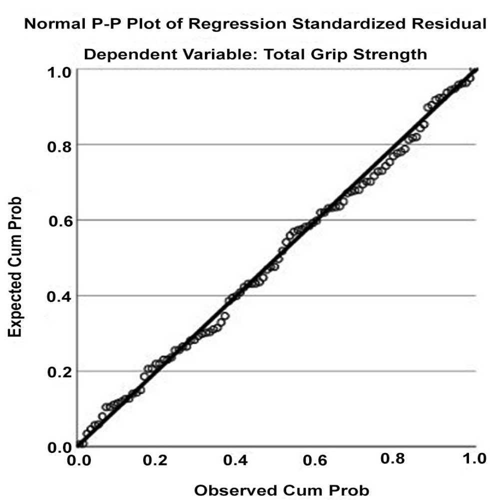

Figure 3: Regression Standardized Residuals of regression between BMI and THGS

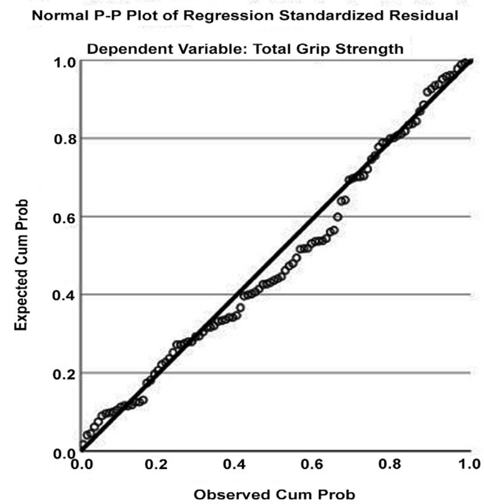

Figure 4: Regression Standardized Residuals of regression between RFAD2 and THGS

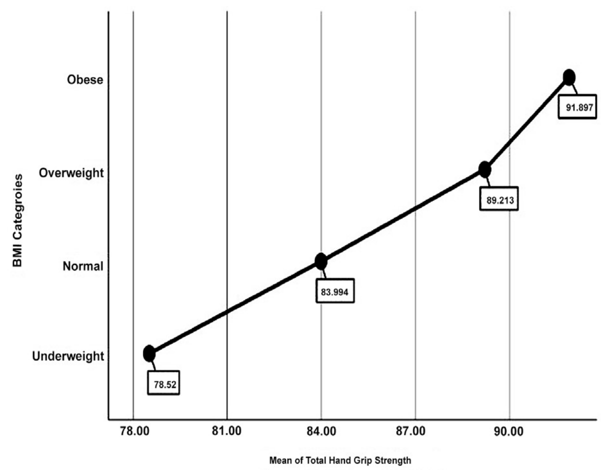

Figure 5: Means of THGS across BMI categories

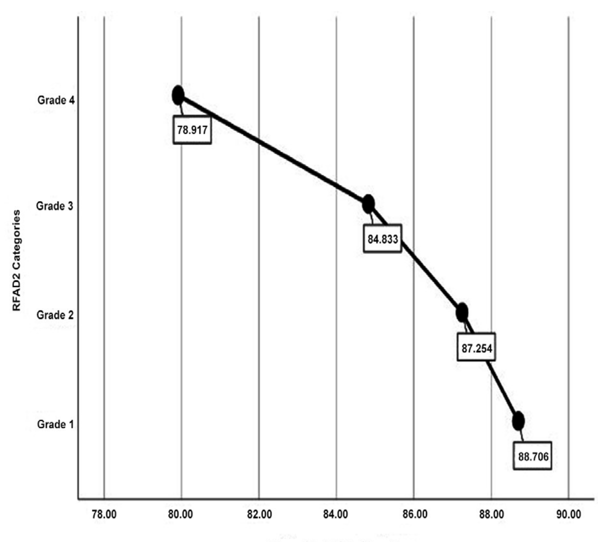

Figure 6: Means of THGS across grades of RFAD2

CONCLUSION

This study examined the associations between total handgrip strength and various anthropometric and morphological markers, including body mass index (BMI), digit ratios (2D:4D), and relative fluctuating asymmetry in digits, while controlling for age. Our findings indicate that weight, height, and BMI are significant positive predictors of THGS, with weight being the strongest predictor. These results align with previous studies demonstrating positive correlations between BMI and handgrip strength among young adults (Ishaq, *et al*., 2022). Notably, participants with higher BMI particularly those who are obese and overweight exhibited significantly greater grip strength compared to those who were underweight or of normal weight. This supports the notion that increased body mass contributes to enhanced muscular strength.

In contrast, 2D:4D did not show significant correlations with grip strength in our sample. This finding is consistent with studies reporting no significant association between 2D:4D ratios and handgrip strength in females (Manning & Fink, 2011; Voracek, *et al*., 2013). However, other research has reported negative correlations between 2D:4D and handgrip strength, particularly in males and athletes, suggesting sex-specific or population-specific variability (Kilduff, *et al*., 2013).

Importantly, our study revealed a robust negative association between the asymmetry in the 2nd digit and grip strength. Higher asymmetry in the second digit was consistently associated with reduced handgrip strength across correlation, regression, and ANOVA analyses. Specifically, participants in the highest relative fluctuating asymmetry in the 2nd digit category exhibited significantly lower total grip strength compared to those with the least asymmetry. This supports the view that fluctuating asymmetry reflects developmental instability and may serve as a biological marker for reduced physical performance (Manning, *et al*., 1998; Van Dongen & Gangestad, 2011).

Collectively, these results suggest that while basic anthropometric measures are strong predictors of muscular strength, morphological indicators of developmental instability such as fluctuating asymmetry may also play an independent role. This underscores the potential utility of relative fluctuating asymmetry as a potential marker of neuromuscular efficiency or developmental health in strength-related performance.

Future research should explore these associations longitudinally and across diverse populations to determine causality and generalizability. Additionally, investigating the underlying biological mechanisms linking fluctuating asymmetry to muscular strength could provide deeper insights into human developmental biology and physical performance.

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