

COMPARISON OF THE 2D:4D RATIO BETWEEN MALE AND FEMALE STUDENTS AT METHODIST ANTIOCHIA PANCURBATU JUNIOR HIGH SCHOOL

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ARTICLE INFO

Article history:

Received : 24 September 2026
Revised : 27 September 2026
Accepted : 30 September 2026
Available online: 01 Oktober 2026

Kata Kunci:

rasio 2D : 4D, dimorfisme seksual,
jari telunjuk, jari manis, remaja

Keywords:

2D : 4D ratio, sexual dimorphism,
index finger, ring finger, adolescents

ABSTRAK

Rasio panjang jari telunjuk (2D) terhadap jari manis (4D), atau rasio 2D:4D, merupakan biomarker noninvasif paparan hormon seks prenatal yang secara konsisten dilaporkan lebih rendah pada laki-laki daripada perempuan. Namun, data rasio ini pada remaja Indonesia masih terbatas. Penelitian ini menganalisis hubungan antara rasio 2D:4D dan jenis kelamin pada siswa SMP Methodist Antiokhia Pancurbatu. Penelitian analitik observasional dengan desain potong lintang ini menggunakan total sampling terhadap 394 responden (198 laki-laki, 196 perempuan). Panjang jari diukur dengan penggaris milimeter, dan rasio dihitung dengan membagi panjang 2D dengan 4D. Data diuji normalitasnya dengan uji

Kolmogorov-Smirnov dan dibandingkan antarjenis kelamin dengan uji Mann-Whitney U. Rerata panjang jari telunjuk dan jari manis masing-masing $6,56 \pm 0,55$ cm dan $6,46 \pm 0,63$ cm, dengan rerata rasio 2D:4D keseluruhan $1,02 \pm 0,10$. Panjang absolut jari berbeda signifikan antara laki-laki dan perempuan, baik pada jari telunjuk ($U = 12539,00$; $Z = -6,119$; $p < 0,001$) maupun jari manis ($U = 12978,00$; $Z = -5,714$; $p < 0,001$), dengan jari laki-laki lebih panjang. Sebaliknya, rasio 2D:4D tidak berbeda signifikan antara laki-laki ($1,018 \pm 0,096$) dan perempuan ($1,025 \pm 0,099$) ($U = 18560,00$; $Z = -0,749$; $p = 0,454$). Temuan ini menunjukkan bahwa dimensi absolut jari mencerminkan dimorfisme seksual pascanatal yang jelas, sedangkan rasio 2D:4D hanya menunjukkan perbedaan yang sangat kecil dan tidak terdeteksi secara statistik pada populasi ini, kemungkinan dipengaruhi oleh presisi pengukuran dan karakteristik sampel.

ABSTRACT

The 2D:4D ratio (index to ring finger length) is a non-invasive biomarker of prenatal sex hormone exposure, consistently reported to be lower in males than in females. However, data on this ratio among Indonesian adolescents remain limited. This study analyzed the correlation between the 2D:4D ratio and sex among junior high school students at SMP Methodist Antiokhia Pancurbatu. An observational analytic cross-sectional study used total sampling of 394 respondents (198 males, 196 females). Finger lengths were measured with a millimeter ruler, and the ratio was calculated by dividing 2D length by 4D length. Data were tested for normality with the Kolmogorov-Smirnov test and compared between sexes using the Mann-Whitney U test. Mean index and ring finger lengths

were 6.56 ± 0.55 cm and 6.46 ± 0.63 cm, with an overall mean 2D:4D ratio of 1.02 ± 0.10 . Absolute finger lengths differed significantly between sexes for both the index finger ($U = 12539.00$; $Z = -6.119$; $p < 0.001$) and ring finger ($U = 12978.00$; $Z = -5.714$; $p < 0.001$), with males having longer fingers. However, the 2D:4D ratio did not differ significantly between males (1.018 ± 0.096) and females (1.025 ± 0.099) ($U = 18560.00$; $Z = -0.749$; $p = 0.454$). These findings suggest that absolute finger dimensions reflect clear postnatal sexual dimorphism, whereas the 2D:4D ratio shows only a very small, statistically undetectable difference in this population, likely influenced by measurement precision and sample characteristics.

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INTRODUCTION

The ratio of index finger (2D) to ring finger (4D) length, or the 2D:4D ratio, compares the lengths of the second and fourth fingers and is believed to serve as an indirect marker of prenatal sex hormone exposure, particularly testosterone and estrogen. This ratio is established during fetal development, and its stability has made the 2D:4D ratio a non-invasive biological indicator used to assess androgen influence during early developmental stages (Ernsten et al., 2023). Amniocentesis studies have found that the 2D:4D ratio correlates negatively with the prenatal testosterone-to-estradiol ratio, meaning a lower 2D:4D ratio corresponds to higher testosterone exposure (Sorokowski & Kowal, 2024).

Differences in the 2D:4D ratio are also linked to sexual dimorphism. Males generally have lower 2D:4D ratios than females due to greater androgen exposure during fetal development (Zhang et al., 2024). Anthropometric studies across various countries have consistently shown this pattern across age groups, from children to adults (Banyeh et al., 2021), establishing the 2D:4D ratio as a stable biological indicator for studying physiological differences between males and females (Lupu et al., 2023). Beyond being a physical trait, the 2D:4D ratio has been linked to various developmental characteristics, including motor ability, psychological function, competitive behavior, and social tendencies. Meta-analyses report that the 2D:4D ratio is associated with children's motor skills, muscle strength, and several behavioral aspects (Fink et al., 2015). Although not a sole determinant, research shows consistent patterns of association between prenatal hormone exposure and behavioral or physiological variation during adolescence and adulthood (Sorokowski & Kowal, 2024; South et al., 2023).

In adults, differences in the 2D:4D ratio between males and females remain clearly evident, with males generally having lower ratios due to higher prenatal androgen exposure. Research over the past five years shows that the adult 2D:4D ratio is related not only to sex differences but also to various health aspects and hormone-influenced physical

traits (Kozieł et al., 2024). Factors such as physical fitness, body composition, and certain behavioral indicators have also been found to correlate with this ratio, and recent studies have highlighted variation in 2D:4D values across populations, underscoring the importance of research across different groups, including adults, to understand the biological patterns present in a given region (Li et al., 2022).

Global population studies also show that differences in the 2D:4D ratio are already apparent in childhood. Adolescent males on average have lower 2D:4D ratios than adolescent females, and this difference is most pronounced in the right hand (the right-hand effect) (Parpa et al., 2024). This finding reinforces that finger-ratio-related sexual dimorphism emerges from early development and remains stable across the lifespan (Ernst et al., 2021). However, research on the 2D:4D ratio in Indonesia remains limited. Most studies have been conducted on adult populations or in clinical contexts, while local data on school-age children, particularly early adolescents, remain scarce. Yet the junior high school period (ages 12–15) is an important phase marked by significant biological, hormonal, and psychological changes (WHO, 2020; Blakemore, 2019). Understanding 2D:4D ratio patterns during this period can provide insight into sexual dimorphism as well as the biological and social development of adolescents in Indonesia.

The 2D:4D finger ratio is determined by dividing 2D length by 4D length on either the right or left hand, and is used as a biological indicator to assess prenatal sex hormone exposure, particularly testosterone and estrogen. This ratio is established during the prenatal phase and remains relatively stable throughout life (Manning, 2021). The prenatal androgen exposure hypothesis explains that high testosterone levels during the prenatal period increase ring finger growth, thereby lowering the 2D:4D ratio, whereas higher estrogen tends to increase the relative length of the index finger, producing a higher ratio. Nevertheless, empirical evidence regarding the strength of the relationship between maternal hormones and children's finger ratios remains mixed, so the 2D:4D ratio is understood to reflect hormonal influence indirectly rather than serving as a substitute for direct hormone measurement.

The 2D:4D ratio is one of the most consistently observed forms of sexual dimorphism in humans, with males tending to have lower ratios than females due to differing exposure to androgen and estrogen hormones during prenatal development, particularly in the first trimester when the bone and cartilage tissue of the fingers forms and responds to hormonal signals. This phenomenon persists into adulthood because finger length does not undergo significant proportional change once the growth period ends, making the 2D:4D ratio a

useful biological indicator for studying physiological differences between males and females, including in research on physical characteristics, behavior, and reproductive health. Although ethnic variation exists in average 2D:4D ratios, the pattern of sexual dimorphism consistently emerges when populations are compared by sex, and this pattern persists even after accounting for other factors.

Research on the 2D:4D ratio is important because this ratio is considered one of the simplest ways to observe hormonal influence from the prenatal period onward. In Indonesia, research on this topic remains very limited, so local data are not yet widely available. In addition, studying the 2D:4D ratio in Indonesia is valuable because the method is simple, inexpensive, and requires no complex equipment, making it well suited for use in schools, community health centers, or field research settings without extensive facilities (Pata et al., 2017). With local data available, researchers can compare finger ratios across different age groups, ethnicities, sexes, and regions, allowing the findings to serve as a foundation for further research in public health, developmental psychology, sports science, anthropology, and other disciplines (Almashali et al., 2023).

The junior high school period, generally spanning ages 12 to 15, is one of the most important developmental phases in an individual's life. During this stage, children enter early adolescence, a period marked by rapid biological and hormonal change, characterized by accelerated height growth, changes in body shape, and reproductive organ development (WHO, 2020). Measuring the 2D:4D ratio among junior high school students in Indonesia can provide insight into the development of sexual dimorphism in the local population (Hoyt et al., 2020), while also enriching local literature on anthropometry and child development and serving as a foundation for further research on the relationship between the 2D:4D ratio and behavior, achievement, and reproductive health (Butovskaya et al., 2023).

Given this limitation in local data, the researchers were interested in examining the correlation between ring and index finger length (2D:4D ratio) and sex among junior high school students at SMP Methodist Antiokhia Pancurbatu, as a representation of the early adolescent population in the area. The research question is whether there is a difference in the index-to-ring finger length ratio (2D:4D) between male and female students at SMP Methodist Pancurbatu. This study aims to determine the relationship or correlation between the ring and index finger length ratio (2D:4D ratio) and sex among adolescents at SMP Methodist Antiokhia Pancurbatu, with the null hypothesis (H_0) stating that there is no

significant difference in the 2D:4D ratio between male and female students, and the alternative hypothesis (H_1) stating otherwise.

RESEARCH METHODS

This study is an observational analytic study with a cross-sectional design, in which measurement of the 2D:4D ratio and identification of sex were carried out at the same time. This design was chosen because it can describe the condition of variables at a single point in time, making it suitable for analyzing the relationship (correlation) and differences (comparison) between index and ring finger length ratio and sex. The study was conducted at SMP Methodist Antiokhia Pancurbatu.

The study population comprised all male and female students at SMP Methodist Antiokhia Pancurbatu. The sample was determined using a total sampling technique, in which all population members meeting the research requirements were included as the sample. This technique was chosen because the population size was relatively manageable, allowing for comprehensive data collection and thus producing more representative and accurate data regarding the overall population condition. Inclusion criteria included students actively enrolled at the school, willing to participate with parental or guardian consent, and having no finger deformities or history of injury to the index or ring finger that could affect measurement results. Exclusion criteria included students who were absent during data collection or who had a history of trauma/deformity to the fingers being measured. Based on these criteria, 394 respondents with complete data (no missing data) were obtained.

Index finger (2D) and ring finger (4D) lengths were measured using a millimeter ruler, measured from the proximal crease to the fingertip, with two measurements taken for each and the average value used. The 2D:4D ratio was calculated mathematically by dividing 2D length by 4D length. Sex was recorded based on school records and numerically coded (male = 1; female = 0) for analysis purposes.

Data processing involved rechecking all finger measurement results to ensure no data were missing or incorrect, after which the data were entered into a statistical program and the 2D:4D ratio calculated. Ratio values were analyzed descriptively to examine the mean and data distribution. A Kolmogorov-Smirnov normality test was then conducted – chosen because the sample size was large ($n > 50$), making it more suitable than the Shapiro-Wilk test, which is more appropriate for small samples ($n \leq 50$) – to determine whether the data were normally distributed. Data were considered normally distributed if

the significance value exceeded 0.05; if normal, an independent samples t-test was used to compare ratios between males and females, while if not normal, the Mann–Whitney U test was used as a non-parametric alternative. Correlation analysis (Pearson for normal data, Spearman for non-normal data) was also conducted to examine relationships between study variables. Results were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Respondent Characteristics

This study involved 394 respondents from two schools with nearly equal proportions: 198 (50.3%) from SMP Methodist 1 and 196 (49.7%) from SMP Methodist 2. By sex, there were 198 male respondents (50.3%) and 196 female respondents (49.7%), a difference of only two respondents.

Table 1. Frequency Distribution of Respondent Characteristics

Characteristic	Category	Frequency (n)	Percentage (%)
School Origin	SMP Methodist 1	198	50.3
	SMP Methodist 2	196	49.7
	Total	394	100.0
Sex	Male	198	50.3
	Female	196	49.7
	Total	394	100.0

Source: Primary data processed, 2026

The near-equal balance between male and female groups is an ideal condition for research comparing the two sexes, as equal sample sizes between groups increase statistical power and minimize bias arising from group size imbalance.

Descriptive Analysis of Study Variables

Descriptive analysis showed that the mean index finger (2D) length among respondents was 6.56 ± 0.55 cm and the mean ring finger (4D) length was 6.46 ± 0.63 cm. Overall, the index finger was slightly longer than the ring finger, resulting in a mean 2D:4D ratio of 1.02 ± 0.10 , indicating that the lengths of the two fingers were relatively similar in this adolescent population. The coefficients of variation ($CV = SD/\text{mean}$) obtained were 8.4% for the index finger, 9.7% for the ring finger, and 9.6% for the 2D:4D ratio, indicating a relatively homogeneous data spread around the mean.

Table 2. Descriptive Statistics of Finger Anthropometric Variables (n = 394)

Variable	Mean	SD	Min	Max	Median
Index Finger / 2D Length (cm)	6.56	0.55	4.50	8.50	6.50
Ring Finger / 4D Length (cm)	6.46	0.63	4.60	9.20	6.50
2D:4D Ratio	1.02	0.10	0.73	1.46	1.00

Source: Primary data processed, 2026

Of all respondents, 35.0% had a ratio value below 1.00 (ring finger longer), 19.0% had a ratio of exactly 1.00 (both fingers measured as equal length), and 45.9% had a ratio above 1.00 (index finger longer). The median ratio was exactly 1.00, with an interquartile range of 0.10. The relatively large proportion of respondents with a ratio value of exactly 1.00 relates to the precision of the measuring instrument and is discussed further in the normality test section.

Descriptive analysis conducted separately for male and female groups is presented in Table 3. This table represents the core of the study's descriptive findings, as it directly illustrates the differences in finger anthropometric values between the two sexes.

Table 3. Descriptive Statistics of Finger Anthropometry by Sex

Variable	Sex	N	Mean	SD
Index Finger Length (2D)	Male	198	6.72	0.53
	Female	196	6.40	0.53
Ring Finger Length (4D)	Male	198	6.64	0.65
	Female	196	6.28	0.56
2D:4D Ratio	Male	198	1.018	0.096
	Female	196	1.025	0.099

Source: Primary data processed, 2026

For absolute length, male respondents consistently had larger measurements than females for both fingers. The mean index finger length for males was 6.72 cm compared to 6.40 cm for females (a difference of 0.31 cm, or approximately 4.90%), and the mean ring finger length for males was 6.64 cm compared to 6.28 cm for females (a difference of 0.35 cm, or approximately 5.63%). In terms of effect size (Cohen's *d*), a value of $d \approx 0.59$ was obtained for both fingers, classified as a medium-to-large effect – indicating a fairly substantial and consistent difference in absolute finger length.

A markedly different pattern was observed for the 2D:4D ratio variable. The mean ratio was 1.018 for males and 1.025 for females, a difference of only 0.006 (0.61%), with an effect size of only $d \approx 0.06$, classified as very small and practically negligible. Although the direction of the difference was consistent with the literature – males tending to have lower ratios (Zhang et al., 2024; Manning, 2021) – the magnitude of the difference in this adolescent population was very slight. This contrast can be understood through the concept of two distinct developmental windows: differences in absolute finger length largely reflect body-size dimorphism developing during puberty (postnatal), whereas the 2D:4D ratio is a marker established during the prenatal period and relatively stable after early childhood (Galis et al., 2010; Manning, 2021). The similarity in the 2D:4D ratio's standard deviation between males (0.096) and females (0.099), combined with nearly identical mean values, reinforces the picture that the distributions of the ratio in both groups overlap substantially.

Normality Test (Kolmogorov–Smirnov)

A normality test was conducted to determine the distribution of each variable as a basis for selecting the appropriate difference test.

Table 4. Kolmogorov–Smirnov Normality Test Results

Variable	Statistic	df	Sig.	Note
Sex	0.342	394	< 0.001	Not normal
Index Finger Length (2D)	0.126	394	< 0.001	Not normal
Ring Finger Length (4D)	0.097	394	< 0.001	Not normal
2D:4D Ratio	0.127	394	< 0.001	Not normal

Source: Primary data processed, 2026

All variables had significance values below 0.001 ($p < 0.05$), so they are statistically classified as not normally distributed. However, this result requires careful interpretation. The sex variable had a much higher Kolmogorov–Smirnov statistic (0.342) than the other variables – a natural consequence of sex being a binary variable that can never be normally distributed by nature (a kurtosis value of -2.010 reflects the bimodal distribution typical of dichotomous data), and this should not be interpreted as a deviation of concern.

For the three finger anthropometric variables, the Kolmogorov–Smirnov statistics were relatively small (0.126 for the index finger, 0.097 for the ring finger, and 0.127 for the 2D:4D ratio), indicating a distribution shape not far from normal. Examination of skewness and kurtosis reinforces this picture: the index finger had a skewness of -0.016 (nearly symmetric) with a kurtosis of 1.015; the ring finger had a skewness of 0.159 with a kurtosis

of 1.108; and the 2D:4D ratio had a skewness of 0.500 (moderate positive skew) with a kurtosis of 1.171 – all within the commonly accepted range indicating a near-normal distribution ($|\text{skewness}| < 2$ and $|\text{kurtosis}| < 7$). This tendency toward leptokurtosis is closely related to the granularity of the measuring instrument (a millimeter ruler reading finger length in increments of 0.1 cm), which causes many values to cluster at the same point – most evident in the 2D:4D ratio, where 19.0% of respondents had a ratio value of exactly 1.00. In addition, normality tests are known to be highly sensitive with large sample sizes ($n = 394$), so even very small deviations can produce a significant p-value – a natural statistical consequence rather than an indication of serious deviation.

Since none of the variables met the assumption of normality, differences between sexes were tested using the non-parametric Mann-Whitney U test.

Mann-Whitney U Test and Inter-Variable Correlation

Table 5. Mann-Whitney U Test Results for Differences in Finger Anthropometry by Sex

Variable	Mann-Whitney U	Z	Sig.	Note
Index Finger (2D)	12539.00	-6.119	< 0.001	Significant
Ring Finger (4D)	12978.00	-5.714	< 0.001	Significant
2D:4D Ratio	18560.00	-0.749	0.454	Not significant

Source: Primary data processed, 2026 (male code = 1, female = 0; $n = 394$)

Index finger (2D) length differed significantly between males and females ($U = 12539.00$; $Z = -6.119$; $p < 0.001$). The higher mean rank for males (232.17) compared to females (162.47) indicates that index finger length tends to be greater in males, with a medium effect size ($r \approx 0.31$). Ring finger (4D) length also differed significantly ($U = 12978.00$; $Z = -5.714$; $p < 0.001$), with males having a higher mean rank (229.95) than females (164.71) and a medium effect size ($r \approx 0.29$). Thus, both components making up the ratio differed significantly between sexes, with males having longer fingers.

In contrast, the 2D:4D ratio did not differ significantly between males and females ($U = 18560.00$; $Z = -0.749$; $p = 0.454$). The close mean ranks between males (193.24) and females (201.81) confirm the absence of a meaningful difference. Based on this result, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected.

A Pearson correlation matrix between variables is presented to explain why the components making up the ratio differ between sexes while the ratio itself does not.

Table 6. Pearson Correlation Matrix of Study Variables

Variable	Sex	Index Finger (2D)	Ring Finger (4D)	2D:4D Ratio
Sex	1	0.286**	0.282**	-0.032
Index Finger (2D)	0.286**	1	0.483**	0.387**
Ring Finger (4D)	0.282**	0.483**	1	-0.613**
2D:4D Ratio	-0.032	0.387**	-0.613**	1

*Source: Primary data processed, 2026. *Correlation significant at the 0.01 level (2-tailed)

Sex was positively and significantly correlated with both index finger length ($r = 0.286$) and ring finger length ($r = 0.282$), confirming the greater absolute length of both fingers in males. Index and ring finger lengths were positively correlated with each other at a moderate strength ($r = 0.483$; $r^2 = 0.233$), showing that the two fingers move together as part of an integrated hand-bone growth pattern. The 2D:4D ratio was positively correlated with index finger length ($r = 0.387$) but fairly strongly negatively correlated with ring finger length ($r = -0.613$) – a direct mathematical consequence of how the ratio is calculated (2D as numerator, 4D as denominator). Most importantly, although both components making up the ratio each differed significantly between sexes, the ratio formed by dividing them did not ($r = -0.032$). This phenomenon is explained by a scale-cancellation mechanism: because both index and ring finger lengths are proportionally larger in males, when the two fingers are divided to form the ratio, the body-size component that distinguishes the sexes cancels out, leaving only the relative proportion, which turns out to be nearly identical between males and females. With a sample size of $n = 394$, this study's statistical power is high, so the non-significant result for the 2D:4D ratio ($r = -0.032$) is unlikely to be due to insufficient statistical power, and is more appropriately interpreted as fairly strong evidence that no meaningful ratio difference actually exists in the population studied.

Discussion

Respondent Characteristics and Overview of Sexual Dimorphism

The respondents in this study were junior-high-age adolescents with a balanced sex composition – a relevant population for studying sexual dimorphism, given they are in an early adolescent phase marked by rapid biological and hormonal changes. The mean 2D:4D ratio of 1.02 in this study falls within the range commonly reported across various populations, though slightly higher than some studies on adult populations using high-precision measuring instruments – a difference that may be influenced by the

measurement method (millimeter ruler) as well as the characteristics of an adolescent population whose finger bones are still growing. The most notable descriptive finding is the differing pattern of sexual dimorphism between absolute finger length ($d \approx 0.59$) and the 2D:4D ratio ($d \approx 0.06$), confirming that although both arise from the same anatomical structure, they carry different biological information: absolute finger length more strongly represents body-size dimensions developing postnatally, while the ratio represents the trace of prenatal hormonal patterns (Galis et al., 2010; Sorokowski & Kowal, 2024).

Difference in Index Finger (2D) Length Between Males and Females

The Mann–Whitney U test results show a significant difference ($p < 0.001$), with males having longer index fingers (6.72 cm vs. 6.40 cm), a medium effect ($d \approx 0.59$). This can be explained by body-size sexual dimorphism that develops during puberty, when the surge in androgen hormones in males drives larger bone growth, including the phalangeal bones of the fingers. Although significant, the effect size is only moderate ($r \approx 0.31$) with considerable distributional overlap, indicating that sex is not the sole determinant of index finger length — much of the variation is determined by other individual factors such as genetics and variation in pubertal stage across the junior-high age range.

Difference in Ring Finger (4D) Length Between Males and Females

The ring finger also differed significantly ($p < 0.001$), with males having longer ring fingers (6.64 cm vs. 6.28 cm), a medium effect ($d \approx 0.59$). An interesting aspect is that the ring finger is known to be particularly sensitive to androgen exposure, as ring finger tissue has higher androgen receptor expression than the index finger, making its growth more strongly influenced by testosterone, both prenatally and during puberty (Manning, 2021; Galis et al., 2010). The significant differences in both fingers are consistent with the strong correlation between them ($r = 0.483$), confirming that the lengths of the two fingers move together as part of an integrated hand-bone growth pattern — yet it is precisely this similar proportional growth that causes the ratio between them not to differ between sexes.

Difference in the 2D:4D Ratio Between Males and Females

The study's main finding shows that the 2D:4D ratio did not differ significantly ($p = 0.454$). Although the direction of the difference was consistent with the literature (males 1.018 vs. females 1.025), the difference was very small and did not reach statistical significance. This finding appears to differ from most of the literature, which consistently reports a lower 2D:4D ratio in males (Zhang et al., 2024; Manning, 2021; Barut et al., 2008), and therefore warrants careful interpretation considering several factors.

The first factor is the inherently small magnitude of 2D:4D ratio dimorphism. A large meta-analysis by Hönekopp and Watson (2010) shows that sex differences in the ratio are only small to moderate in size, with substantial distributional overlap; a radiographic study by Schiergens et al. (2025) on children and adolescents likewise confirms large within-sex variation. The second factor is the measurement method — a millimeter ruler reading finger length in increments of 0.1 cm may not be sensitive enough to capture ratio differences that the literature reports as typically only 0.01–0.03; Hönekopp and Watson (2010) specifically found that less precise measurement methods tend to produce smaller differences and lower reliability, consistent with the findings of Butovskaya et al. (2023). The third factor relates to which hand was measured: the literature consistently shows a right-hand effect, i.e., a clearer ratio difference in the right hand (Parpa et al., 2024; Schiergens et al., 2025); if this study's measurements were not specifically focused on the right hand, an already-small true difference could become even harder to detect. The fourth factor is the characteristic of the adolescent population, who are still in active growth, meaning the dimorphic pattern of the ratio established prenatally may not yet be sharply expressed at this age.

The absence of a difference in the ratio contrasts sharply with the clear difference in absolute finger length, indicating that this study was indeed able to detect sexual dimorphism of a fairly large magnitude (absolute finger length) but not dimorphism of a very small magnitude (the ratio, which reflects prenatal hormonal patterns) — consistent with the mathematical explanation seen in the correlation matrix. It should be emphasized that this non-significant result does not necessarily refute the existence of 2D:4D ratio sexual dimorphism reported extensively elsewhere. As shown by Parpa et al. (2024), the 2D:4D ratio cannot be used to determine an individual's sex personally due to high overlap, even though at the population level males tend to have lower ratios. This finding is more appropriately interpreted as an indication that 2D:4D ratio dimorphism in this local adolescent population, measured with a millimeter ruler, is too small to be statistically detected — not as evidence that such dimorphism does not exist.

Study Limitations

This study has several limitations. First, finger length measurement using a millimeter ruler has lower precision compared to digital calipers, radiography, or digital image analysis — contributing to data clustering (19.0% of ratios measured exactly at 1.00) and potentially making it harder to detect small ratio differences. Second, the hand measured was not specifically focused on the right hand, whereas the literature shows ratio dimorphism is most apparent in the right hand (the right-hand effect). Third, the cross-

sectional design only describes conditions at a single point in time and does not control for pubertal stage, even though junior-high-age adolescents are at varying stages of puberty. Fourth, the study population was limited to a single school environment with a particular ethnic background, so generalization of results should be made with caution.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study on the correlation between the index and ring finger length ratio (2D:4D ratio) and sex among students at SMP Methodist Antiokhia Pancurbatu, the following conclusions can be drawn: (1) the mean index finger (2D) length among respondents was 6.56 ± 0.55 cm and the mean ring finger (4D) length was 6.46 ± 0.63 cm, with male respondents having greater absolute lengths for both fingers compared to females, for both the index finger (6.72 cm vs. 6.40 cm) and the ring finger (6.64 cm vs. 6.28 cm); (2) the mean 2D:4D ratio among respondents was 1.02 ± 0.10 , with relatively similar values between males (1.018) and females (1.025) – the direction of the difference is consistent with the concept of 2D:4D ratio sexual dimorphism (lower in males), although the magnitude is very small; (3) there was no significant difference in the 2D:4D ratio between male and female students ($U = 18560.00$; $Z = -0.749$; $p = 0.454$), so H_0 is accepted and H_1 is rejected; (4) absolute index finger length ($Z = -6.119$; $p < 0.001$) and ring finger length ($Z = -5.714$; $p < 0.001$) each differed significantly between males and females, with males having longer fingers, even though the ratio between the two did not differ; and (5) these findings indicate that sexual dimorphism in the adolescent population studied is clearly apparent in absolute finger length (reflecting body-size dimorphism during puberty), but is not detected in the 2D:4D ratio, due to the cancellation of the body-size component when the ratio is formed, as well as the inherently small magnitude of ratio dimorphism, which is difficult to detect using a millimeter ruler.

For future researchers, it is recommended to use higher-precision measuring instruments such as digital calipers, radiography, or computerized image analysis, to specifically measure the right hand (the right-hand effect) while comparing it with the left hand, and to control for pubertal stage (Tanner stage) as a variable. Research on broader and more ethnically and geographically diverse populations, as well as longitudinal designs, should also be considered to obtain more representative results. For the fields of anthropometry and medicine, this study's findings underscore the importance of distinguishing between absolute finger length and the 2D:4D ratio as two biological entities with different meanings, and that the 2D:4D ratio is a subtle biological marker of prenatal

hormone exposure that cannot be used to determine an individual's sex personally, but only reflects general patterns at the population level.

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