

# Measurement of 2D:4D Ratio and Neck Circumference in Adolescents: Sexual Dimorphism and its Implications in Obesity – A Cross Sectional Study

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## Abstract

**Introduction:** A bidirectional relationship between testosterone and obesity is explained by the hypogonadal obesity cycle and evidence from reports stating that weight loss leads to increased testosterone levels. There is an alarming rise in the prevalence of obesity among children and adolescents. The objectives of the present study were to measure the 2D:4D ratio of adolescent students and study its association with neck circumference (NC). **Materials and Methods:** After obtaining ethical clearance, the study was conducted on 168 adolescents pursuing their undergraduate education in a South Indian university. 2D:4D ratio and NC were measured using Digital Vernier Calipers and plastic inch tape, respectively. All the participants were divided into three groups (normal, overweight, and obese) on the basis of their BMI. Mean 2D:4D ratio and NC were compared between the three groups using one-way ANOVA. **Results:** Mean right and left hand ratios of the study population were  $0.973 \pm 0.030$  and  $0.975 \pm 0.069$ , respectively. Comparison of 2D:4D ratios between the sexes revealed statistical significance (males = 0.966, females = 0.977, and  $P$  value = 0.019). There was no significant correlation between 2D:4D ratios and BMI. There was a significant negative correlation between NC and 2D:4D ratios of the individuals with normal BMI. However, no statistically significant correlation between NC and 2D:4D ratios was observed in overweight and obese individuals. **Conclusion:** 2D:4D ratio and NC could be used as simple measures for screening of people at higher risk for heart disease and metabolic syndrome. However, studies on a larger sample might help us reveal the association between NC and 2D:4D ratios.

**Keywords:** 2D:4D ratio, digit ratio, neck circumference, obesity, prenatal testosterone

## INTRODUCTION

Sexual dimorphism in digit ratios has been studied in various racial and ethnic groups and it has been observed that 2D:4D is negatively related to prenatal testosterone and positively associated with prenatal estrogen.<sup>[1]</sup> Literature search revealed interesting associations between 2D:4D ratio and increased sperm counts, increased risk for heart disease, obesity and metabolic syndrome, depression, and anxiety.<sup>[2-4]</sup> The formation and maintenance of the cardiovascular system is sensitive to testosterone and estrogen in men. 2D:4D ratio, being a putative marker for in utero levels of these hormones, is expected to exhibit sexual dimorphism in the risk of development of cardiovascular disease.<sup>[5]</sup>

NC has been reported as a risk marker for cardiovascular diseases.<sup>[6,7]</sup> Based on the independent associations of 2D:4D ratios and NC with obesity and risk of heart disease, the

objectives of the present study were to compare the 2D:4D ratios of adolescents of 18–19 years of age between sexes, in groups based on BMI, and then correlate 2D:4D ratio with NC.

## MATERIALS AND METHODS

### Ethical considerations

The study was initiated after obtaining ethical clearance (008/07/2016/IEC/SU). Information sheet with pertinent information was given to all the participants invited to

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participate in the study. Written informed consent was obtained from all participants of the study.

### Study setting and population

The present cross-sectional study was conducted on 168 adolescents of 18–19 years of age, of both sexes (67 males and 101 females) pursuing their undergraduate education in Physiotherapy in a South Indian university. Participants with any history of injury/surgeries/congenital abnormalities of the second and fourth digits or the neck and participants with goiter/any neck swellings were excluded from the study.

### Measurement of 2D:4D ratio

2D:4D ratio was measured from both the hands. The digit lengths were measured using a Digital Vernier Caliper. Two measurements were taken from both the hands by the same examiner. The examiner was trained and calibrated prior to the conduct of the experiment. The ratio was calculated by dividing the mean index finger lengths (mm) and mean ring finger lengths (mm) for the right hand.

### Estimation of BMI

BMI of the participants was calculated by the given formula after the measurement of height and weight of the participant.<sup>[8]</sup> BMI = weight (kg)/(height (m) × height (m)).

### Measurement of Neck Circumference

NC was measured at the level of the upper margin of the thyroid cartilage. In men, with a laryngeal prominence (Adam’s apple), measurements were taken below the prominence. All circumference measurements were taken at the end of expiration with a plastic tape measuring within 1 mm.<sup>[3]</sup> It was measured by a single trained examiner in order to avoid the investigator bias. In order to make the measurements precise, NC was measured twice and the mean is calculated. The cutoff levels used for the NC determined were NC ≥37 cm for men and ≥34 cm as indicators of obesity.

### Statistical analysis

Data analysis was done using SPSS 17.0. Based on the BMI, the whole population was divided into three groups (normal, overweight, obese), using the standard cutoff values.<sup>[9]</sup> The mean 2D:4D ratios and NCs of the three groups were compared using one-way ANOVA.

## RESULTS

The mean age of the study participants ( $n = 168$ ) was  $18.6 \pm 0.791$  years. The mean anthropometric measures and 2D:4D ratios of the study participants are presented in Table 1. Unpaired Student’s *t*-test revealed no significant difference between the 2D:4D ratios of left and right hands ( $t = -0.406$ ,  $P = 0.685$ ). However, comparison of 2D:4D ratios between the sexes showed statistical significance [Table 2].

The study participants were classified into three groups based on their BMI – normal (46.4%), overweight (25%), and obese (28.6%). Chi-square analysis showed that the females showed significant increase in the number

of overweight and obese individuals when compared to males ( $P = 0.016$ ) [Table 3].

It is a well-known fact that BMI and the NC are strongly correlated and indicative of obesity and metabolic syndrome. The results of the present study reiterated the fact with similar findings of highly significant correlation between the BMI and NC ( $r = 0.459$ ,  $P < 0.0001$ ). Correlation between BMI and 2D:4D ratios of right and left hands revealed no statistical significance in the study population [Table 4]. Similarly, correlation between NC and 2D:4D ratios of right and left hands also did not reveal any statistical significance in the study population [Table 4].

Table 5 shows the correlation between NC and 2D:4D ratios in the subjects after they were grouped as normal, overweight, and obese based on their BMI. There was a statistically significant negative correlation between the NC and 2D:4D ratios of the normal individuals of the study group. Lower the 2D:4D

**Table 1: Mean anthropometric measures and 2D:4D ratios of study participants**

Measure	Mean	SD
Weight (kg)	58.78	13.335
Height (cm)	155.46	8.779
BMI (kg/m <sup>2</sup> )	24.3093	5.02028
Neck circumference (cm)	32.6065	2.73944
Right 2D:4D	0.973	0.030
Left 2D:4D	0.975	0.069

**Table 2: Comparison of 2D:4D ratios between males and females**

Ratio	Sex	Mean	Std. deviation	<i>t</i> -Statistic	<i>P</i>
Right 2D:4D	M	0.966	0.031	-2.379	0.019*
	F	0.977	0.03		
Left 2D:4D	M	0.963	0.033	-2.198*	0.030*
	F	0.983	0.085		

\*Equal variances not assumed

**Table 3: Sex-wise classification of study participants based on BMI**

Sex	Normal	Overweight	Obesity	Chi square	<i>P</i>
Female	38 (37.6)	28 (27.7)	35 (34.7)	8.259	0.016*
Male	40 (59.7)	14 (20.9)	13 (19.4)		

\* $P < 0.05$  was considered to be statistically significant

**Table 4: Correlation between 2D:4D ratios and BMI and NC**

Measure	BMI Pearson correlation coefficient	<i>P</i>	NC Pearson correlation coefficient	<i>P</i>
Right 2D:4D	0.019	0.803	-0.121	0.118
Left 2D:4D	0.120	0.120	-0.055	0.479

**Table 5: Correlation between NC and 2D:4D ratios in normal, overweight, and obese individuals**

Measure	Normal		Overweight		Obese	
	Pearson correlation coefficient	P	Pearson correlation coefficient	P	Pearson correlation coefficient	P
Right 2D:4D	-0.283	0.012*	0.011	0.943	0.011	0.943
Left 2D:4D	-0.136	0.234	-0.047	0.763	-0.131	0.376

ratios, higher the NC in the normal individuals. However, no statistically significant correlations between NC and 2D:4D ratios were observed in the overweight and obese individuals in both sexes.

## DISCUSSION

Literature review reported a bidirectional relationship between testosterone and obesity, which in turn has been explained by the hypogonadal obesity cycle. Testosterone has been reported to be protective against heart disease, obesity, and metabolic syndrome.<sup>[10]</sup> Further, recent reports have also stated that weight loss resulted in increased testosterone levels. Therefore, it could be hypothesized that individuals with high digit ratios (lesser exposure of testosterone in utero) would be more prone to obesity and coronary heart disease.

There is an alarming increase of obesity among children and adolescents. Individuals with BMI greater than or equal to 30 are considered to be obese, according to the WHO. Recent reports have also shown that NC positively correlated with the risk of metabolic syndrome.<sup>[11]</sup> Based on these independent associations of 2D:4D ratios and NC with obesity and risk of heart disease, the present study aimed to explore the relationship between 2D:4D ratio and NC.

Among the 168 participants, in the present study, there was no significant difference between right and left-hand 2D:4D ratios. However, the comparison of 2D:4D ratios between the sexes revealed statistical significance. This was concurrent with the reports of Manning *et al.*<sup>[12]</sup> In a study on association of digit ratios to ethnicity, the 2D:4D ratio was lower in males than in females and this was significant for the Uygur, Han, and Jamaican samples. On the other hand, Jacob *et al.* showed higher digit ratios in males in comparison to females.<sup>[13]</sup> Nonsignificant differences between 2D:4D ratios between the sexes were observed in the adolescents by Austin *et al.* and Bull *et al.*<sup>[14]</sup>

In the present study, the participants were divided into three groups – normal, overweight, and obese on the basis of BMI scores. The prevalence of overweight and obese individuals in the present study was 25% and 28.6%, respectively. Of this, there was a significant increase in the number of overweight and obese individuals among females when compared to males. The prevalence of overweight and obese in Tamil Nadu was 24.6% and 26.6%, respectively. However, the prevalence of overweight among adolescents was found to be 14.3% among boys and 9.2% among girls, whereas the prevalence of obesity was 2.9% in boys and 1.5% in girls.<sup>[15]</sup>

The correlation of BMI with right and left 2D:4D ratios did not reveal any statistical significance. This was in concurrence with the findings of Jacob *et al.* However, it was contradictory to the reports of Fink *et al.*, who showed a positive correlation between the digit ratio and BMI of males. The significance was observed only for left hand 2D:4D ratios.<sup>[3]</sup> In addition, in the present study, there was no significant correlation between NC and 2D:4D ratios of left and right hands. This was contradictory to Fink *et al.* who reported a positive correlation between NC and left- and right-hand ratio, although not statistically significant.<sup>[3]</sup>

The correlation between NC and 2D:4D ratios of males and females did not reveal any statistical significance in the current study. This was contradictory to Fink *et al.* and Aksu *et al.* The former showed a significant positive correlation between 2D:4D ratios and NC only for males but not for females. The latter showed a positive correlation between right-hand ratios and NC, only for males. It is a well-known fact that BMI and NC are strongly correlated and they are indicators of obesity and metabolic syndrome.<sup>[16]</sup> The results of the present study also showed a highly statistically significant correlation between the BMI and NC measured in the participants.

In the present study, when the participants were further subgrouped based on BMI, there was no significant correlation between NC and 2D:4D ratios of overweight and obese individuals. However, there was a statistically significant negative correlation between the NC and 2D:4D ratios of the normal individuals – lower the 2D:4D ratios, higher the NC in the normal individuals. Significant negative correlations were found between the left- and right-hand 2D:4D ratios, waist-and-hip circumference, and waist-hip ratio (WHR) of females.<sup>[17]</sup> Existing literature showed a significant positive association between right-hand 2D:4D ratios with WHR in men, whereas the hip circumference was found to correlate significantly negatively with right-hand 2D:4D ratio.<sup>[3]</sup> However, literature search did not yield any existing major reports on the relationship between NC and 2D:4D ratios.

## CONCLUSION

The present study gives us an insight into the role of prenatal androgen exposure (reflected by 2D:4D ratio) in the risk of development of metabolic syndrome or CHD. 2D:4D ratio and NC could be used as simple measures for screening of people at higher risk for CHD and metabolic syndrome. The significant correlation between NC and 2D:4D ratios was only observed in individuals with normal BMI. However, studies on a larger sample might help us reveal the association between

NC and 2D:4D ratios in overweight and obese individuals also. If such an association between NC and 2D:4D ratio could be established, then 2D:4D ratio can be used as a marker for obesity, way earlier in an individual's life.

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### Conflicts of interest

There are no conflicts of interest.

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