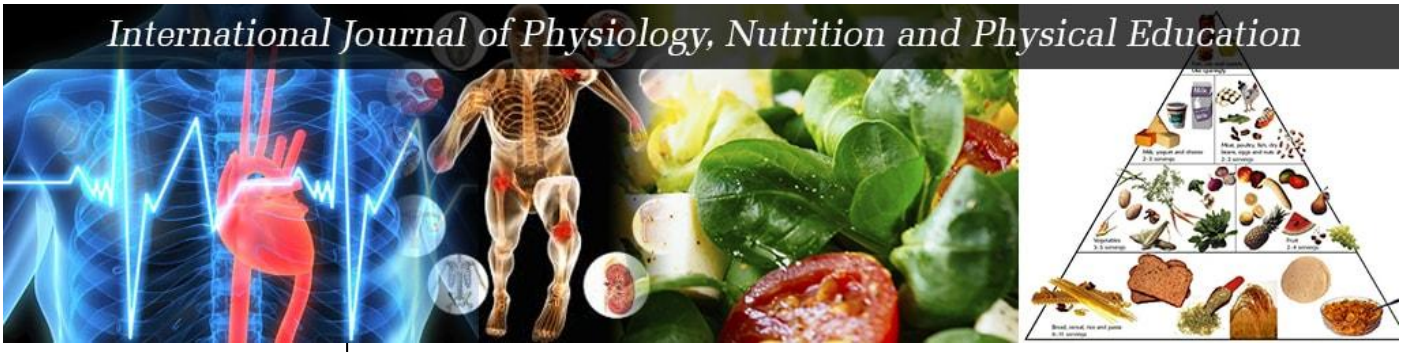

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Visuospatial task performance is not correlated with 2D:4D ratio in medical students

Bijli Nanda and Prajna Paramita Samanta

Abstract
Introduction: The second digit to fourth digit (2D:4D) ratio, has been suggested to be responsible for many gender differences, including differences in cognitive functions. Visuospatial functions have been found to be better in men. However, reports are not consistent. Hence, we aimed to explore these issues in detail.
Methods: 2D: 4D ratios of right hand were calculated from scanned images. All participants performed a Mental Rotation task (MRT) using a computer based software and scores were recorded. Correlations between 2D:4D ratios and MRT scores were computed.
Results and conclusion: Men performed slightly better on the MRT. Scores declined with increases in 2D:4D ratios in men. An opposite pattern was seen in women. No correlations were found between 2D:4D and MRT scores, Visuospatial function is affected by, but not correlated with 2D:4D ratio. Other factors like age and education, may modify the effect of 2D:4D on visuospatial function.

Keywords: 2D:4D, mental rotation, prenatal testosterone

Introduction
The ratio of the lengths of different digits or fingers is known as the digit ratio; measured from the midpoint of the most proximal crease of the finger (at its junction with the hand) to the tip [1]. The ratio of the length of the index finger to ring finger shows sexual dimorphism. This ratio is referred to as the 2D: 4D ratio. In males, the ratio is usually less than 1 and females have a higher ratio [2, 3]. However, studies on 2D:4D from the Indian population are limited. Moreover, some of these studies have found conflicting results [4, 5]. 2D:4D ratio has been used by many researchers as an indirect measure of prenatal androgen exposure [6]. Many gender differences in humans seem to stem from differences in foetal testosterone/oestrogen levels and may be attributed indirectly to the 2D:4D, including cognitive functions. Amongst cognitive functions, the most consistent gender differences have been shown for "Mental Rotation" (MR) task. The MR task is a test of visuospatial function where the individual must compare figures which have been rotated at various angles and decide whether they are the same or different. Men have been reported to perform better than women in the mental rotation task and other visuospatial tasks [7, 8]. However, there are some conflicting reports. A recent study in aviation screeners found no such gender differences [9]. A positive correlation has been suggested between prenatal testosterone levels and mental rotation in girls. A negative correlation was suggested for boys and adult males [10, 11]. Education has been shown to affect cognitive function [12]. Hence, we proposed to determine the correlation, if any, between 2D:4D ratio with "Mental Rotation" in male and female medical student volunteers from a college in North India

Materials and Methods
The study was carried out in a medical university in North India on right handed healthy undergraduate student volunteers (19-25yrs). The study was approved by the Institutional Ethics committee of the University. Participants were recruited for the study after putting up a notice for voluntary participation. Written informed consent was obtained from the volunteers. Any individual with hand deformity was excluded from the study. Those who had a history of hypertension, heart disease or were unable to perform the handgrip exercise for other reasons were also excluded from the study.

The height was measured on a stadiometer and weight in Kilograms was noted on a digital weighing scale (*Salter*). In addition, the following specific measurements were carried out.

2D:4D ratio

All participants were asked to place both their hands, fingers together, on the surface of a scanner (*Canon MP258*). Scanned images were saved as pdf documents. The lengths of the second (2D) and fourth digits (4D) of both hands were measured from the tip of the finger to the ventral proximal crease using the "measurement tool" in Adobe. In case, there was a band of creases at the base of the digit, measurements were done from the most proximal of these. The measurements were done twice and the average was calculated [13]. The 2D:4D ratio was computed separately for each hand.

Mental Rotation Task [MRT]

Cognitive function was assessed using the Mental Rotation task, which the volunteers performed after registration at https://home.cambridgebrainsciences.com/en/public/tests.

Subjects were shown a series of pairs of 2-dimensional objects, where they had to mentally rotate the objects to detect if they were the same or different. Accordingly, they had to click "match" or "mismatch" respectively. The total time for the test was 90 seconds. The scores were calculated by the software based on the number of correct and incorrect responses within the stipulated time.

Statistical analysis

Statistical analysis was done using analysis toolpak in MS excel. Descriptive statistics was used to determine Mean +/- SD values for 2D:4D ratios and mental rotation scores. Unpaired t-test was done to look for any significant gender differences in 2D:4D ratio of each hand and in mental rotation scores. Effect sizes (Hedge's g) for differences between men and women were calculated. Correlation between 2D:4D ratios and MR scores was calculated using Pearson's correlation [14].

Results & Discussion

76 women and 65 men participated in this study. 2D:4D ratios of the right hand and left hand were significantly less for males as compared to females [Table 1]. The effect size for right hand was 0.548 and 0.604 for the left hand.

Table 1: 2D:4D ratios of males and females for the Right and Left hand

	Males [Mean +/-SD]	Females [Mean +/- SD]	Significance of difference in means (P)
2D:4D [Right]	0.96+/-0.036	0.98+/-0.032	$P<0.01$
2D:4D [Left]	0.95+/-0.033	0.97+/-0.030	$P<0.001$

Mental rotation scores of males [58.95+/-4.32] was found to be higher as compared to females [53.7+/-4.4]. However, the difference was not statistically significant. The effect size for the difference in MR scores was 0.138(Hedge's g). In males, MR scores tended to decline with an increase in 2D: 4D of both hands. MR scores showed a tendency to increase with right and left 2D:4D ratios in females (Fig 1, 2). However, no significant correlations were detected.

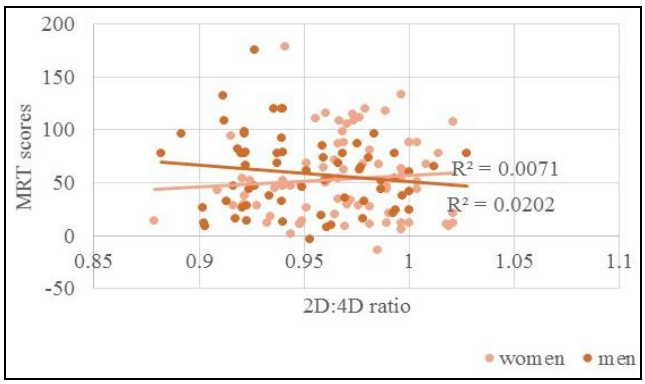

Fig. 1: Correlation of Left Hand 2D:4D ratio with MRT scores

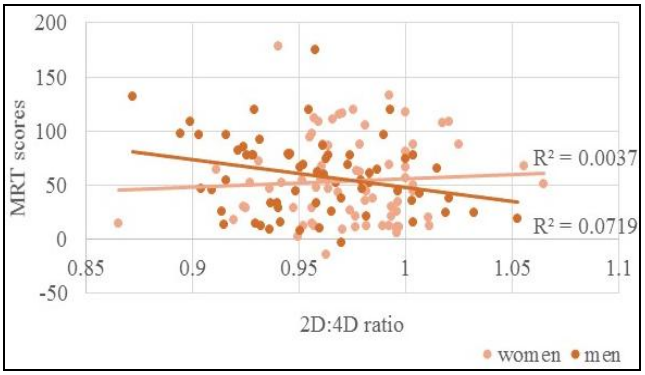

Fig. 2: Correlation of Right Hand 2D:4D ratio with MRT scores

As with many studies [2, 15], we found a significant difference between the 2D: 4D ratios of males and females, for both, the right and the left hand. Studies on males from Central India showed a lower Right hand 2D:4D ratio compared to females, as with our studies. In contrast, in the South Indian population a significantly higher Right hand 2D:4D ratio was found for males when compared to females. No significant differences were reported for the left hand for either central or south Indian individuals [4, 5]. It seems probable that gender differences in 2D: 4D ratios may be ethnicity dependent. Our study sample was majorly from North India, which may account for the differences observed. However, more studies are needed for a better understanding of these differences.

Most studies report that men outperform women in MR tasks. Such results have been seen with 3-Dimensional as well as 2-Dimensional objects used for the tests. It has been suggested that the sex differences increase with the level of difficulty of the test, irrespective of whether the objects are 2-D or 3-D [16]. In our study, we observed that males performed slightly better than females in the Mental Rotation task, but the differences in scores were not significant. A study on engineering students also found similar results but did not comment on significance [17]. There are only few studies that reported no gender differences. A recent study on aviation screeners found no gender differences in a mental rotation task. They also reported that scores in these individuals were less than in the control population [9]. It is possible that gender differences are only apparent above a threshold. The scores of our participants may be below this threshold, which might explain why we did not find any significant gender differences. However, we were unable to test this as our sample size was small. Another explanation could be the similar levels of education of students who participated in this study. Education may play a role in modulating cognitive abilities [12] and may reduce gender differences. However, a more extensive study is need for further clarification. The better

spatial ability of men as compared to women is partly mediated by the extent of previous exposure to spatial activities [18]. Accordingly, education and previous experience may predict performance on MRT. Our study population was first year medical students, hence had a similar educational background. This may explain partly, why we found no significant differences between men and women,.

A significant association between 2D:4D and a wide range of cognitive functions has been reported, thought to be mediated by prenatal testosterone [PT]. PT may modulate the development of functional cerebral asymmetries and subsequent performance on a range of cognitive tasks. PT levels may negatively affect the development of the left side of the brain, but positively affect development of the right side of the brain [19, 20]. In adult males, modulation of brain structure by PT levels may account for the correlation of 2D:4D ratio with total cerebral cortex [21]. Differences in structure of the parietal lobe [8], anterior hippocampus volume [22, 23] and differential influence of prenatal testosterone on brain organization [24] are amongst some of the other explanations suggested for observed differences in mental rotation and other cognitive functions in males and females. Our results on the correlation of 2D:4D ratio and mental rotation show a pattern similar to studies in children [10]. The difference in pattern of correlations [positive in females and negative in males], even though not significant; suggests that there are subtle differences in mental rotation abilities between males and females, and these may depend on 2D:4D ratio/PT. Similar trends for negative correlations in males have been found by others [25]. An inverse- U shaped pattern for males and a U- shaped pattern for females has been observed between testosterone and spatial ability [26]. Appropriate levels of testosterone may be needed for certain cognitive functions [27]. Higher testosterone levels may inhibit spatial ability. It is possible that beyond a threshold of PT, the correlation pattern between 2D:4D and MR performance shifts from negative [as in males] to positive [as in females]. A limitation of our study is the small sample size. However, our sample size was all from the same age group and with similar educational background, which lacks in many previous studies reported on a wide age range and young adults of variable educational background.

Conclusion

Our studies found that men performed slightly better on a Mental Rotation task. Mental Rotation scores showed a tendency to decline with an increase in 2D:4D ratio in men whereas an opposite pattern was seen in females. We conclude that 2D:4D does affect visuospatial function, but the extent of its contribution may be modified by other factors like age and education. More studies are needed for clarity.

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Conflict of interest: none

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