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Short Communication

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Second Digit Length, Fourth Digit Length and Second to Fourth Digit Ratio (2D:4D): Relevance in the Choice of Female Footballer Athletes and Female Non-Footballer Athletes in Nigeria

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ABSTRACT

Several studies have shown the importance of anthropometric measurements as a veritable tool in forensic science, crime detection, as well as a means of studying variations in human populations. The present study focused on using digit lengths and ratio to determine sports skills. A total of 270 female subjects comprising of sports and non-sports participants were measured. Seventy of which were non-footballer athletes, 100 were footballer athletes, and 100 were non-sports participants. The second and fourth digits of their right and left hands were measured using a digital vernier caliper. The data obtained from the participants were analyzed by SPSS. Subjects who participated in football also possessed athletic skills, hence both have similar traits. This study has shown that athletic and football skills are similar, as the values obtained from the above parameters were not significant at $p<0.05$. The results showed that digit ratio is not a good tool for determining sport skills, as compared to digit lengths (2D and 4D). No difference was observed between the digit ratio of the sports participants and those of non-sports participants. Digit lengths (2D and 4D) were found to be significant determinants of sports, with sports groups showing significantly shorter digits. Therefore, the findings of this study suggest an association between digit lengths and sporting abilities.

KEY WORDS: Football; Female footballer athletes; Female non-footballer athletes; Second to fourth digit ratio and Nigeria.

INTRODUCTION

Digit ratio is the ratio of the length of the different digits or fingers typically measured from the midpoint to the bottom crease where the finger joins the hand to the tip of the finger.[1-4] Second and fourth digit ratio (2D:4D) is the ratio of the length of the second digit to that of the fourth digit. The fourth digit is the ring finger of the human hand and the second most ulnar finger located between the middle finger and the little finger. While the second digit is the index finger, which is the first finger and the second digit of the human hand.[2,5]

A number of authors have reported correlation between second to fourth digit ratio and ethnic diversity, as well as between 2D:4D and gender and testosterone level.[6] It was found

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that females have longer second digit as compared to the fourth digit and higher 2D:4D, while the reverse is the case for males.[7-9] This is also associated with height and weight.[10] Data from nine native populations from different international regions indicated large variations in mean 2D:4D between the populations. High 2D:4D were recorded for participants of native England, Spain and Poland, while intermediate 2D:4D values were recorded for participants from Hungary, Germany and India; a low 2D:4D values were observed for participants from South Africa, Jamaica and those of Finland. Males tend to have a lower 2D:4D compared to females. Many females from the low 2D:4D populations had lower ratios than males from the high 2D:4D populations.[6]

In Nigeria, there was no significant difference in digit ratio between the Yoruba and Igbo ethnic groups, but a significant difference in digit ratio between the males and the females of each ethnic group has been reported, as the males have higher digit ratio compared to the females.[11] However in another study, the Urhobo and Igbo ethnic groups of Nigeria were compared, the result indicated that digit ratio varies according to ethnic group. Among the Igbos and Urhobos, males have shorter digit ratio than the females.[12]

Low 2D:4D has been reported to be associated with faster skiing speed on a timed downhill slalom run, even after the effects of sex, age and skiing experience were removed.[13] The 2D:4D digit ratio is regarded as a physiological marker for the prenatal concentration of the sex hormones; testosterone and estrogen which organizes the architecture of the body and brain, and the distribution of the hormones receptors.[14]

When testosterone increases in later life it activates these pre-existing structures, because pre-natal testosterone is stable. It follows that it can be adequately measured at any time as opposed to blood or saliva testosterone which fluctuates diurnally and can be significantly influenced by many variables.[15,16] This was first indicated by the clear sexual dichotomy of 2D:4D, with men having lower ratios compared to women. This coincides with the occurrence that women prenatally have a higher ratio of estrogen to testosterone while men prenatally have a higher ratio of testosterone to estrogen and therein lays the significance of digit ratio. A low digit ratio is associated with high prenatal testosterone and low estrogen while a high digit ratio is associated with low prenatal testosterone levels and high estrogen levels. The specific reason for this sex hormone influence upon 2D:4D digit ratio is that: "Testosterone appears to stimulate the prenatal growth of the fourth digit while estrogen promotes the growth of the second digit".[17] Further evidence for this digit specific relationship with prenatal sex hormones comes from the finding that the fourth digit appears to be more sensitive to androgens than the second digit; this is evident because it is far more likely to have hair growing on the middle segment (phalanx 2) of the digit. Hair on this same segment of the second finger is far less likely. Hair growth in this position is dependent on testosterone and more specifically the metabolically active form of testosterone, dihydrotestosterone (DHT). Winkler and Christiansen found hair growth on the phalanx 2 of fingers to be positively related to testosterone. The phalanx 2 hair growth is the least on the second finger of the whole hand which suggests that it is less sensitive to testosterone and more sensitive to estrogen.[18]

It has also been found that there is difference between which hand is being measured. The concentrations of various hormones in men and women have been found to be more strongly represented in the right hand than in the left hand.[17,19]

It may be that digits lengths on the right hand are more sensitive to early androgen exposure than those on the left.[20-23] The occurrence of the lateralization of hands in the expression of testosterone/estrogen concentrations taken from the ventral surface of the hands, showed lower ridge counts and pattern intensity in right hand compared to left where testosterone is low, as in women,[24-26] and higher ridge counts and pattern intensity in the right hand compared to the left hand when testosterone concentrations are high, as in males.[27]

These 'dermatoglyphic' patterns are fixed before the nineteenth week in-utero, therefore suggesting relationships between prenatal androgens and the formation of the epidermis and dermis upon the hands. Hormones other than testosterone and estrogen that have been found to be associated with digit ratio also show hand lateralization. Concentrations of luteinizing hormone and prolactin which are positively correlated with 2D:4D digit ratio, are also expressed more strongly in the right hand.[17]

The biological occurrence that links 2D:4D to prenatal sex hormone is when a fetus is exposed to prenatal testosterone from two sources: The fetal testes and the adrenal glands. The main source of prenatal estrogen comes from the placenta and the adrenal glands through the aromatase conversion of testosterone from the maternal blood stream.[28] The developmental differentiation of fetal gonads is greatly influenced by these fetal sources of steroids.[29] The differentiation of the fetal gonads is controlled by the homeobox or *Hox* genes.[30] In particular, the posterior most *Hox-d* and *Hox-a* genes are strongly expressed in the urino-genital system including the gonads; however, these genes are also required for the growth and differentiation of digits and toes.[20] This common control of the differentiation of digits and gonads has allowed aspects of gonadal functions such as the production of testosterone and estrogen to affect the development of the digits.

Variation in digit ratio has also been attributed to differences in the distribution, frequency and sensitivity of androgen and estrogen receptors.[19] Therefore, 2D:4D can be more specifically said to repress.

Recently, in an attempt to examine whether circulating concentrations of sex hormones and sex hormones binding

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globulin (SHBG) measured in adulthood was associated with 2D:4D, Muller and colleagues noted weak associations between any adult circulating concentration of sex hormone or SHGB and 2D:4D. Their results contributed to the growing body of evidence indicating that 2D:4D is unrelated to adult sex hormone concentrations.[31]

Published data on sporting ability and 2D:4D has mainly focused on male participants. The 2D:4D ratio has been reported to be negatively correlated with testosterone levels and positively associated with estrogen levels in adults.[32] Studies by other researchers [4,6,33,34] have shown that in humans, finger length ratio of the index and ring finger (2D:4D) is a sexually dimorphic trait. The ratio between the length of the index and the ring digit (2D: 4D) may correlate within utero testosterone levels because, it is sexually dimorphic. From previous studies it could be said that professional players have a significantly lower 2D: 4D (derived from left and right 2D: 4D) compared with controls.[35,36]

MATERIALS AND METHODS

Electronic digital calipers (with a resolution of 0.01 mm, an accuracy of 0.03 mm and a repeatability of 0.01 mm) was used to measure the subjects' right and left digit lengths. The subjects were given verbal briefing on the nature of the research, mode of measurement and procedure. Subjects with normal digits were selected at random and no known history of anomalies at different stadia and football training fields were seen.

A total of 270 female subjects all in Rivers State were selected. This comprised of 70 non-footballer athletes, 100 footballer athletes, and 100 non-sports participants. The participants with band of crease at the base of the digit, the second most proximal crease were measured. After informed consent was obtained from the subjects, measurements were made with the digital caliper and the two parameters that were measured include the right and left second and fourth digits. All measurements were taken in millimeters with caliper.

The non-footballer athletes and footballer athletes were taken as the sports participants.

RESULTS

Table 1 shows the mean values of 2D, 4D and Digit ratio (2D: 4D) for the female non-footballer athletes and female footballer athletes. The mean values obtained for both right and left digit length (2D and 4D) of non-footballer athletes were R2D, R4D: 68.89±5.63 mm, 69.59±5.68 mm, L2D, L4D: 68.98±5.13 mm, 69.71±5.65 mm and the digit ratios (2D: 4D) were R2D: 4D; 0.990±0.044, L2D:4D; 0.988±0.037. The mean values obtained for the right and left digit length (2D and 4D) of footballer athletes were R2D, R4D: 68.34±5.64, 68.75±5.33, L2D, L4D: 68.36±5.96 and 68.69±5.50 and the digit ratios (2D: 4D) were R2D: 4D; 0.990±0.050, L2D:4D; 0.995±0.044. The values obtained for the non-footballer athletes and footballer athletes were similar as there were no significant difference observed (p>0.05). This suggests that athletic skill and football skill are similar. Those who can play football probably possess athletic skills.

Table 2 is for mean 2D, 4D and 2D: 4D of females who were good in athletics (non-footballer athletes) and those who were not good in any sports (non-sports participants). The mean values obtained for both right and left digit lengths (2D, 4D) of non-sports participants were R2D, 4D: 71.69±6.39 mm, 72.05±6.49 mm, L2D, 4D: 70.90±6.88 mm, 71.64±6.29 mm and the digit ratios were R2D: 4D; 0.995±0.033, L2D:4D; 0.989±0.035. When the mean values obtained for the female non-footballer athletes and the female non-sports participants were compared, it was found that the non-sports females had longer second and fourth digit length than their counterparts who are good in athletics (non-footballer athletes) (p<0.05). The difference were significant in both hands of the groups (p<0.05). The digit ratio (2D: 4D) was however, not significantly different (p>0.05). Thus (2D: 4D) may not be useful in differentiating non-footballer athletes from non-sports females.

Observations in table 2 were similar to those of Table 3. When the mean values of the female footballer athletes were compared with those of non-sports participants, significant differences were observed in 2D and 4D in both hands of the two groups with female footballer athletes showing shorter 2D and 4D lengths (p<0.05) than non-sports participants females. The 2D: 4D ratio was however, not significantly different between the groups (p>0.05). Observations from the present study have shown that females with sport skill (non-footballer athletes and footballer athletes) possess similar traits and hence similar second and fourth digits lengths. These observations were the same in both hands. Their digit ratios were equally similar, although not a good indices when comparing different sport skills.

DISCUSSION

From this study, it was observed that digit ratio in females cannot be a good criterion in distinguishing sports participants from non-sports participants because no significant difference was observed between the two. This is consistent with the finding of Sudhakar et al[37] who noted among males, but not female swimmers a significantly (p<0.05) lower 2D:4D ratio.

Also from the similarities in low digit ratio of sports participants, it could be deduced that footballer athletes can also participate in athletics due to their low digit ratio. On the other hand, digit length can be used to distinguish between sports and non-sports participants, as sports participants presented low second and fourth digit length compared to non-sports participants. Similarly, low second and fourth finger lengths were related to increased female sports ability and it may predict potential sports ability. This is in agreement with the findings of Arthur and colleagues; Bouchardm, Malina et al.[5,38] The present study revealed that females with sports skills possessed similar second

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Table 1: Descriptive Statistics and *Z*-test Comparing 2D, 4D and Digit Ratio (2D:4D) for Female Non-Footballer Athletes and FemaleFootballer Athletes at *p*<0.05.

Parameters	Non-footballer athletes Mean±SD	Footballer athletes Mean±SD	*Z*- test
R2D (mm)	68.89±5.63	68.34±5.64	0.63
R4D (mm)	69.59±5.68	68.75±5.33	0.97
R2D:4D	0.99±0.044	0.99±0.050	0.00
L2D (mm)	68.98±5.13	68.36±5.96	0.73
L4D (mm)	69.71±5.65	68.69±5.50	1.17
L2D:4D	0.99±0.037	1.00±0.044	0.11
	n=70	n=100	

R=Right, L=Left, D=Digit, SD=Standard deviation, n=Sample size

Table 2: Descriptive Statistics and *Z*-test Comparing 2D, 4D and Digit Ratio (2D:4D) for Female Non-football Athletes and Non-Sports Females at *p*<0.05.

Parameters	Non-footballer athletes Mean±SD	Non-sports female Mean±SD	*Z*- test
R2D (mm)	68.89±5.63	71.69±6.39	3.02
R4D (mm)	69.59±5.68	72.05±6.49	2.62
R2D:4D	0.99±0.044	1.00±0.033	0.79
L2D (mm)	68.98±5.13	70.90±6.88	2.08
L4D (mm)	69.71±5.65	71.64±6.29	2.09
L2D:4D	0.99±0.037	0.99±0.035	0.18
	n=70	n=100	

R=Right, L=Left, D=Digit, SD=Standard deviation, n=Sample size

Table 3: Descriptive Statistics and *Z*-test Comparing 2D, 4D and Digit Ratio (2D:4D) for Female Football Athletes and Non-Sports Females.

Parameters	Female footballer athletes Mean±SD	Non- sports females Mean±SD	*Z*- test	Significant difference
R2D (mm)	68.34±5.64	71.69±6.39	3.93	Yes
R4D (mm)	68.75±5.33	72.05±6.49	3.93	Yes
R2D:4D	0.990±0.050	0.995±0.033	0.79	No
L2D (mm)	68.36±5.96	70.90±6.88	2.79	Yes
L4D (mm)	68.69±5.50	71.64±62.29	3.53	Yes
L2D:4D	0.995±0.044	0.989±0.035	1.09	No
	n=100	n=100		

R=Right, L=Left, D=Digit, SD=Standard deviation, n=Sample size

and fourth digit lengths and similar traits, which is also in agreement with the findings of Manning and Bundred.[39] Hence, a relevant criteria in sports selection among female non-footballer athletes.

Researchers have also reported significant negative correlations between digit ratios and sporting abilities in female non-football athletes.[13,35,40]

Using a precise radiographic phenotype,[40] provided evidence that low 2D:4D is related to increased running and sporting ability in women. The authors postulated that 2D:4D is a predictor of potential sports ability and that the understanding of the mechanisms underpinning this relationship would give important insights into musculoskeletal fitness, health and disease. This report is not in agreement with our finding since digit ratio is not a potential predictor of sporting abilities but digit lengths (2D and 4D).

The observed differences in the findings above may be due to the nature of sport played, wide range of ethnic diversity of digit ratios,[40] digit lengths as well as method of measurement

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applied. However, in sporting activities, athletic skills are required; that is why a good footballer must know how to run in addition to his kicking and dribbling abilities in order to win or outsmart his/her opponent during competition.

CONCLUSION

This study was done to determine the second and fourth digit ratio of female sports and non-sports participants in Rivers State of Nigeria, and to establish a relationship between sporting abilities. The findings of this study suggest an association between digit lengths and sporting abilities.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. Mayhew TM, Gillam L, Mcdonald, R, Ebling FJ. Human 2D (index) and 4D (ring) digit lengths: Their variation and relationships during the menstrual cycle. *J Anat.* 2007; 211 (5): 630-638. doi: 10.1111/j.1469-7580.2007.00801.x

2. Fink B, Manning J, Neave N, Tan U. Second to fourth digit ratio and hand skill in Austrian children. *Biol Psychol.* 2004; 67 (3): 375-384. doi: 10.1016/j.biopsycho.2004.03.012

3. Fink B, Manning J, Neave N, Grammer K. Second to fourth digit ratio and facial asymmetry. *Evol Hum Behav*. 2004; 25(2): 125-132. doi: 10.1016/S1090-5138(03)00084-9

4. Ibegbu AO, Danjuma ZC, Hamman WO, Umana UE, Ikyembe DT, Musa SA. Anthropometric study of the index (2nd) and ring (4th) digits in ebira ethnic group of Nigeria. *Asian J Med Sci.* 2012; 4(2): 79-84.

5. Arthur RM, Beetner DG, Ambos HD, Cain ME. Improved estimation of pericardial potentials from body-surface maps using individualized torso models. *J Electrocardiology.* 1998; (31 Suppl): 106-113. doi: 10.1016/S0022-0736(98)90301-6

6. Manning JT, Barley L, Walton J, et al. The 2nd: 4th digit ratio, sexual dimorphism, population differences and reproductive success: Evidence for sexually antagonistic genes? *Evol Hum Behav.* 2000; 21(3): 163-183. Web site. https://hungary.pure.elsevier.com/en/publications/the-2nd-4th-digit-ratio-sexual-dimorphism-population-differences-. Accessed November 21, 2016.

7. Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Hum Reprod.* 1998; 13(11): 3000-3004. doi: 10.1093/humrep/13.11.3000

8. McIntyre MH. The use of digit ratios as markers for perinatal androgen action. *Reprod Biol Endocrinol*. 2006; 4: 10. doi: 10.1186/1477-7827-4-10

9. Hönekopp J, Watson S. Meta-analysis of digit ratio 2D:4D shows greater sex difference in the right hand. *Am J Hum Biol*. 2010; 22(5): 619-630. doi: 10.1002/ajhb.21054

10. Augustine OI, Zubair CD, Wilson OH, Uduak, EU, Daniel I, Sunday AM. Association of the index (2nd) and ring (4th) digit ratios with some physical attributes in Ebira ethnic group of Nigeria. *Appl Technol Innov.* 2012; 7(2): 46-49.

11. Oladipo GS, Fawehinmi HB, Ezon-Ebidor E, Osunwoke A, Ordu KS. Second to fourth digit ratio in Nigeria Igbos and Yorubas. *Scientific Research and Essay.* 4 2009; (10): 1146-1148. Web site. http://www.academicjournals.org/article/article1380617806_Oladipo%20et%20al.pdf. Accessed November 21, 2016.

12. Oladipo GS, Olotu EJ, Gwunireama IU. Second to fourth digit ratio in Nigeria Igbo and Urhobos. *Scientific Research Essay*. 2006; 2(14): 53-54.

13. Manning JT. The ratio of 2nd to 4th digit length and performance in skiing. *J Sports Med Phys Fitness*. 2002; (42): 446-450. Web site. http://www.pubpdf.com/pub/12391439/The-ratio-of-2nd-to-4th-digit-length-and-performance-in-skiing. Accessed November 21, 2016.

14. Manning J, Bundred P, Newton D, Flanagan B. The second to fourth digit ratio and variation in the androgen receptor gene. *Evol Hum Behav.* 2003; 24(6): 399-405. doi: 10.1016/S1090-5138(03)00052-7

15. Olweus D, Mattsson A, Schalling D, Low H. Circulating testosterone levels and aggression in adolescent males: A causal analysis. *Psychosom Med.* 1988; (42): 253-269. Web site. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.335.5882. Accessed November 21, 2016.

16. Ross R, Bernstein L, Judd HR, Hanisch R, Pike M, Henderson B. Serum testosterone in healthy young black and white men. *J Natl Cancer Inst.* 1986; (76): 45-48.

17. Manning JT. *Digit Ratio: A Pointer to Fertility, Behavior and Health.* New Brunswick, Canada, New Jersey, USA and London, UK: Rutgers University Press; 2002; 518-530.

18. Winkler EM, Christiansen K. Sex hormone levels and body hair growth in Kung San and Kavango men from Namibia. *Am J Phys Anthropol.* 1993; (92) 155-164. Web site. http://www.pubpdf.com/pub/8273828/Sex-hormone-levels-and-body-hair-growth-in-Kung-San-and-Kavango-men-from-Namibia. Accessed November 21, 2016.

19. Tanner JM. *Foetus into Man: Physical Growth from Concep-*

ISSN 2473-4772 http://dx.doi.org/10.17140/ANTPOJ-2-109

tion to Maturity. Cambridge, MA, USA: Mass Harvard University Press; 1990: 430-436.

20. Csatho A, Osvath A, Bicsak E, Karadi K, Manning JT, Kallai J. Sex role identity related to the ratio of second to fourth digit length in women. *Biol Psychol.* 2002; 62 (2): 147-156. doi: 10.1016/S0301-0511(02)00127-8

21. Brown WM, Hines M, Fane B, Breedlove SM. Musculinized finger length ratios in humans with congenital adrenal hyperplasia (CAH). *Horm Behav.* 2001;(3): 325-326. doi: 10.1006/hbeh.2002.1830

22. Barley L, Manning JT, Walton J. The second fourth digit ratio, sexual dimorphism, population difference and reproductive success: Evidence for sexually antagonistic genes. *Evolution and Human Behavior.* 2000; 21(3): 163-183. doi: 10.1016/S1090-5138(00)00029-5

23. Marshal D. The heritability of 2nd to 4th digit ratio in humans. England: Doctoral dissertation, University of Liverpool; 2000: 17-19.

24. Kimura D, Carson MW. Dermatoglyphic asymmetry: Relation to sex, handedness and cognitive pattern. *Pers Individ Dif.* 1995;(19), 471-478. doi: 10.1016/0191-8869(95)00076-I

25. Jamison CS, Meier RJ, Campbell BC. Dermatoglyphic asymmetry and testosterone levels in normal males. *Am J Phys Anthropol.* 1993; (90): 185-198. doi: 10.1002/ajpa.1330900205

26. Holt SB. The genetics of dermal ridges. Frequency distribution of total finger-ridge count. *Ann Hum Genet.* 1955; (20): 159-170. doi: 10.1111/j.1469-1809.1955.tb01365.x

27. Penrose LS. Finger-print pattern and the sex chromosomes. *Lancet.* 1967; (1): 298-300. doi: 10.1016/S0140-6736(67)91237-8

28. George FW, Griffin JE, Leshin M, Wilson JD. Endocrine control of sexual differentiation in humans. In: Novy MJ, Resko JA, eds. *Fetal Endocrinology*. New York, USA: Academic Press; 1981: 341-357.

29. Lording DW, De Kreter DM. Comparative ultrastructural and histochemical studies of the interstitial cells of the rat testis during fetal and postnatal development. *J Reprod Fertil.* 1972; 29(2): 261-269. doi: 10.1530/jrf.0.0290261

30. Zakany J, Duboule, D. Hox genes and the making of sphincters. *Nature*. 1999; (45): 401-761. doi: 10.1038/44511

31. Muller DC, Giles GG, Bassett J, et al. Second to fourth digit ratio (2D:4D) and concentrations of circulating sex hormones in adulthood. *Reprod Biol Endocrinol*. 2011; 9: 57. doi: 10.1186/1477-7827-9-57

32. Manning JT, Scutt D, Wilson J, Lewis-Jones DI. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Human Reproduction.* 1998; 13(11): 3000-3004. doi: 10.1093/humrep/13.11.3000

33. Baker F. Anthropological notes on the human hand. *Am Anthropol*. 1888; 1: 57-75. doi: 10.1525/aa.1888.1.1.02a00040

34. George R. Human finger types. *Anatomical Records.* 1930; 46(2): 199-204. doi: 10.1002/ar.1090460210

35. Hönekopp J, Manning JT, Muller C. Digit ratio (2D:4D) and physical fitness in males and females: Evidence for effects of prenatal androgens on sexually selected traits. *Hormone Behavior.*2006; 49: 545-549. doi: 10.1016/j.yhbeh.2005.11.006

36. Voracek M, Reimer B, Dressler SG. Digit ratio (2D:4D) predicts sporting success among femalefencers independent from physical, experience, and personality factors. *Scand J Med Sci Sports.* 2010; 20: 853-860. doi: 10.1111/j.1600-0838.2009.01031.x

37. Sudhakar HH, Veena UB, Tejaswi RN. Digit ratio (2D:4D) and performance in Indian swimmers. *Indian J Physiol Pharmacol*. 2013; 57(1): 72-76.

38. Bouchard C, Malina RM, Perusse L. *Genetics of Fitness and Physical Performance.* Champaign, IL, USA: Human Kinetics; 1997: 213-219.

39. Manning JT, Bundred PE. The ratio of 2nd to 4th digit length: A new predictor of disease predisposition. *Med Hypotheses.* 2000;54: 855-857. doi: 10.1054/mehy.1999.1150

40. Paul SN, Kato BS, Hunkin JL, Vivekanandan S, Spector TD. The Big Finger: The second to fourth digit ratio is a predictor of sporting ability in women. *Br J Sports Med*. 2006; 40: 981-983. doi: 10.1136/bjsm.2006.027193