

Physical Fitness And Digit Ratio (2D:4D) In Male Students From Wrocław, Poland

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ABSTRACT

There is sex-difference in humans as regards aerobic efficiency, physical strength and endurance and the sex difference is greatly dependent upon differential concentration of testosterone during different phases of growth and development including the intrauterine phase or prenatal growth. Second-to-fourth digit lengths ratio (2D:4D) is an putative indicator of prenatal testosterone exposure. Lower 2D:4D indicates higher prenatal testosterone exposure and vice versa. Males generally have lower 2D:4D than females. This cross-sectional study investigated the relationship between the fitness measures and 2D:4D in young adult Polish males. The study included 118 Polish male students first course in General Kościuszko Military Academy of Land Forces in Wrocław. Their mean (\pm SD) age was 20.4 (\pm 1.60) years. Eurofit test set was employed to assess physical fitness. Apart from height, weight, second and fourth digit lengths, hand grip strength was also measured by a standard isometric dynamometer. The study showed a weak relationship between 2D:4D of right hand and results of physical fitness tests. The smaller was the 2D:4D, the better was the result of endurance and strength tests. This finding was in accord with reports by other studies, indicating that individuals with smaller 2D:4D tend to perform better in these aspects of physical ability. However, we also found an opposite relationship with the results to agility tests. Male students with higher 2D:4D scored better in 5x10 meters shuttle run. This finding did not match with results reported by other studies. This study indicated towards possibility that an association between low 2D:4D and sport and athletic achievement and also physical performances were due to, at least in part, the action of prenatal testosterone. Further studies are required to investigate the relationship of fitness parameters with digit ratio and ultimately with prenatal testosterone exposure.

Key words: Eurofit test, 2D:4D, digit ratio, testosterone, male, Poland

Introduction

Endurance in humans is thought to have developed as long back as 2 million years ago in order to adapt to selection pressure in favour of successful chasing of games¹. Modern humans exhibit sex-difference as regards aerobic efficiency. Evidences show that men are in some way physiologically more adaptive than women in terms of aerobic endurance. For instance, they have lower oxygen uptake while running at a standard speed². The sex difference in humans is, to a large extent, dependent upon differential concentration of testosterone during different phases of growth and development including the intrauterine phase or prenatal growth. We may therefore expect that the dif-

ferential concentration of this hormone may have a link with endurance and fitness qualities in humans. Indeed there was evidence that the 'organisational' effect of prenatal testosterone (PT) exposure on brain had a role in the relative superiority of males over females in endurance based sports^{3,4}.

The ratio of second-to-fourth digit lengths (2D:4D) also indicate the relative concentration of intrauterine testosterone as a proxy morphological indicator in human^{5,6}. This ratio shows negative correlation with prenatal testosterone (PT) and a positive correlation with prenatal oestrogen (PE)⁷. Experimental studies on animal model also strongly supported this fact^{8,9}. PT seems to lengthen the fourth finger, whereas prenatal oestrogen

TABLE 1
DESCRIPTIVE STATISTICS OF RESULTS OF PHYSICAL FITNESS TEST, AGE AND BODY SIZE FOR THE MALE STUDENTS OF MILITARY COURSE

	N	mean	SD
Run 1000 m [s]	118	199.14	10.03
Bent Arm Hang [s]	118	52.35	14.11
Sit-Up [n]	118	32.00	4.07
10 x 5 meters Shuttle Run [s]	118	19.08	1.07
Standing Broad Jump [m]	118	221.23	16.87
Handgrip strength right hand [kG]	118	63.30	7.66
Handgrip strength left hand [kG]	118	60.21	7.58
Sit-and-Reach [cm]	118	11.86	6.19
Flamingo Balance Test [n]	117	9.29	4.81
Height [cm]	118	75.55	8.19
Weight [kg]	118	180.04	6.21
BMI [kg/m ²]	118	23.27	1.80
Age [years]	118	20.40	1.58

lengthens the index finger⁷. In comparison to females, male foetus experiences higher levels of PT, and as a result, tends to have longer 4D relative to 2D than do females, i.e., male 2D:4D < female 2D:4D^{5,10}. This ratio is determined by the relative proportions of PT and PE in

a narrow window period during foetal development⁸ and these difference is revealed at the end of first trimester^{11,12}. Afterwards, 2D:4D may increase slightly with growth; but the change is small and is little affected by pubertal changes^{13,14}.

Lower 2D:4D was very often found correlated with activities and performances requiring greater physical ability, e.g., a significant negative correlation with handgrip strength was found among males¹⁵. In a meta-analysis, it was observed that athletic ability was negatively correlated with 2D:4D for both sexes in both hands; better performance in training for endurance running was associated with low 2D:4D, in both men and women¹⁶. In another recent study, it was shown that low 2D:4D was associated with endurance-linked running, and the association was more prominent among females¹⁷.

The studies conducted on the relationship between sporting, exercise endurance and digit ratio had mostly relied on the *a priori* selection of subjects engaged in sporting activities or had a previously achieved ranks in their respective fields^{4,18,19}. A recent study, conducted on the Flemish girl children aged 6-18 years, found no relationship between 2D:4D and fitness measures related to health or skill²⁰. The study, however, considered only the left 2D:4D. Keeping in view of this limited sex and hand specific applicability and the growing evidences on the relative importance of right hand 2D:4D¹⁶, it becomes an urgent necessity to undertake more of such studies not only among children but also on adults.

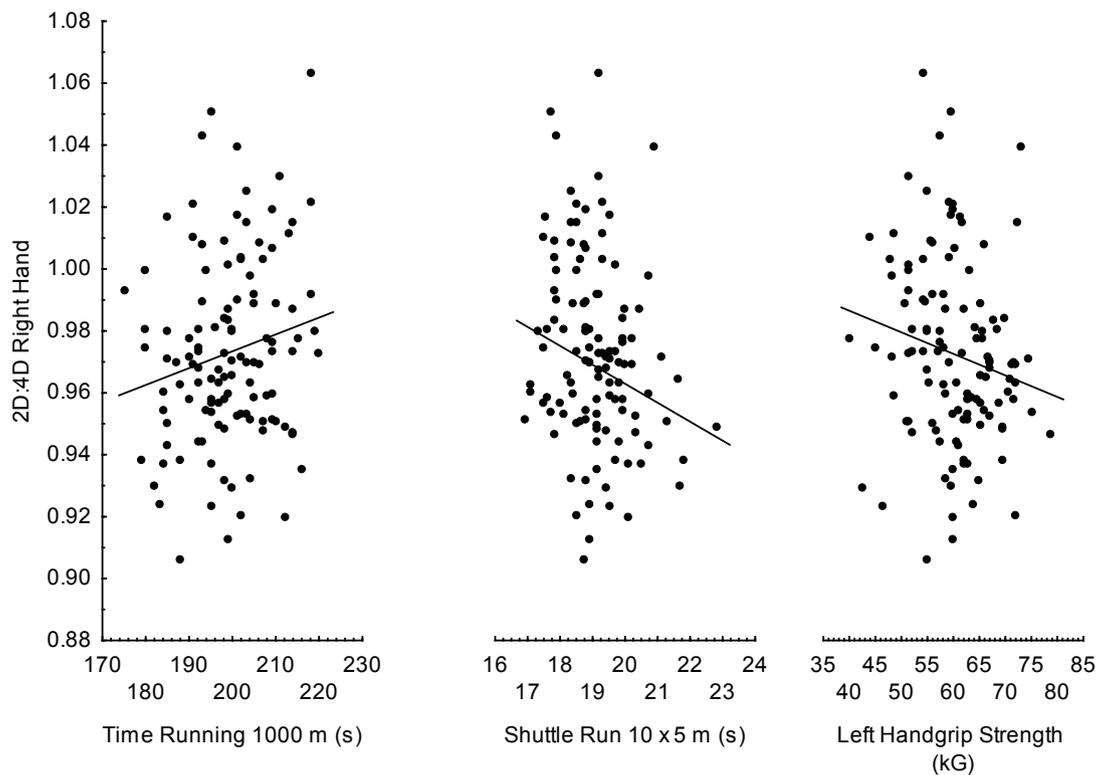


Fig. 1. Scatterplots presenting the relationship between 2D:4D of right hand and results of two physical fitness tests.

The Eurofit tests set is a reliable and well tested method of assessment of physical fitness. It can evaluate both fitness skills and the health related physical abilities²¹. These tests are now widely used in research for their relative operational simplicity²². There is paucity of studies relating fitness measures and 2D:4D, especially with direct measures of the former. The only very recent study which dealt with direct measures of fitness in relation to digit ratio also used Eurofit method and found that lower 2D:4D (higher prenatal testosterone) was associated with higher scores in almost all the tests²³. The present study therefore attempted to assess the relationship between the fitness measures and 2D:4D in young adult Polish males. To the knowledge of the present authors this was the maiden study on adults of such kind till date.

Materials and Methods

Subjects and setting

The study was cross-sectional and included 118 male students of first course in General Kuściuszko Military Academy of Land Forces in Wrocław (GKMALF) during 2012-13. The study protocol followed the ethical guidelines of Helsinki Declaration²⁴. Official permission from the Chancellor of GKMALF and informed consent from the participants were obtained before and during study, respectively. The participants were enrolled in military course (cadets) to become professional soldiers²⁵. The cadets generally begin with 4-week military training and live in barracks inside the academy. Leaving this area is highly restricted and needs special permission of the authority. The day begins after waking up at 6 am with 3 kilometres run. After classes cadets again participate in trainings and sport exercises. During the semester-breaks cadets take part in army range training and in army unit services.

Anthropometry

All measurements, tests and questionnaire were carried out during October 2012 year. Age was recorded from the official record of the academy. The lengths of the second (2D) and fourth digit (4D) of each hand were measured to the nearest 0.1 mm with a digital calliper (TESA SHOP-CAL) following standard procedure⁵. In every tenth student the length of digits were measured twice in order to calculate the intra observer error of measure, which varied between 0.17 mm for 4D of left hand and 0.21 mm for 4D of right hand, and was to from 366 to 440 times lower than average length of 4D of left hand and 4D of right hand, respectively. The ratio of 2D to 4D (2D:4D) was calculated as the length of the 2D divided by the length of the 4D for each hand. Height was recorded to the nearest 1 mm and weight to the nearest 500 g following a standard protocol²⁶. Hand grip strength (HGS) was measured by a standard isometric dynamometer (Saehan Corporation, South Korea).

Fitness tests

Eurofit tests set²¹ were employed to assess physical fitness and endurance²¹. Additionally, 1000 meters run test was executed. All these tests were carried out in the sport centre of GKMALF by one of the authors (MK). The following physical tests were performed.

1000 meters Run: On the command „run”, the participants run around sport stadium in a group not exceeding 15 persons. At the finish the time was recorded using sport counter.

Bent Arm Hang Test: The participant was assisted into a hanging position on a horizontal bar. The body was lifted to a height with assistance so that the chin was in level with the bar. The bar was to be held with overhand grip (palms are facing away from body), the shoulders width apart. The time count started as the subject was released to attempt to hold them in the position for as long as possible until the chin falls below the level of the bar or the head tilted backward to enable the chin to stay at the bar level.

Sit-Up Test. The participant lied on their back on floor with the knees bent at right angles, the feet held down by a partner and fingers inter locked behind the head. On a command, they raised the head and trunk close to knees and again returned to floor. It continued maximum for 30 seconds and number of sit-ups recorded.

10x5m Shuttle Test. Marked cones and/or lines were placed five meters apart. Participants placed a foot at one marker and on instruction ran to the opposite marker, turned and returned to the starting line, repeated five times without stopping (covering 50 meters total). At each marker both feet must fully cross the line. The total time taken to complete 50 m was recorded. The lesser time taken the better was fitness.

Standing Long Jump (Broad Jump): The participant stood behind a line marked on the ground with feet slightly apart. Both feet take-off and landing with swinging of the arms and bending of the knees to provide forward drive was allowed. The subject jumped as far as possible, landing on both feet without falling backwards. The length of the distance covered was recorded.

Sit-and-Reach: Subjects sat on the floor with legs out straight ahead; feet (shoes off) were placed with soles kept flat against a box and shoulder-width apart. Both knees were held flat against the floor by the tester. With hands on top of each other and palms facing down, the subject reached forward along the measuring line as far as possible. After one practice reach, the second reach was held for at least two seconds while the distance was recorded, making sure of no jerky movements; the fingertips remained at same level and the legs flat.

Flamingo Balance: The participant stood on a beam without shoes, keeping balance by holding instructor's hand. While balancing on the preferred leg, the free leg is flexed at the knee and its foot held close to buttock. A stopwatch started to record the time of holding balance in this position and was stopped each time the person lost

Table 2

Results of multiple linear regressions for results of physical fitness tests (dependent variable) and BMI, height, age and 2D:4D for right and left hand (independent variables).

	Right hand			Left Hand		
	Beta	t	p	Beta	t	p
Run 1000 m [s]						
BMI	-0.01	-0.08	n.s.	-0.01	-0.10	n.s.
Height	-0.04	-0.47	n.s.	-0.04	-0.45	n.s.
2D:4D	0.19	2.01	< 0.05	0.05	0.49	n.s.
Age	0.06	0.64	n.s.	0.13	1.37	n.s.
Bent Arm Hang [s]						
BMI	-0.39	-4.52	< 0.001	-0.39	-4.49	< 0.001
Height	-0.04	-0.50	n.s.	-0.04	-0.52	n.s.
2D:4D	-0.01	-0.01	n.s.	-0.02	-0.21	n.s.
Age	0.19	2.16	< 0.05	0.19	2.16	< 0.05
Sit-Up [n]						
BMI	0.01	0.15	n.s.	0.02	0.20	n.s.
Height	-0.13	-1.41	n.s.	-0.14	-1.46	n.s.
2D:4D	0.03	0.35	n.s.	-0.04	-0.46	n.s.
Age	0.05	0.48	n.s.	0.04	0.43	n.s.
10 x 5 meters Shuttle Run [s]						
BMI	-0.04	-0.46	n.s.	-0.04	-0.47	n.s.
Height	0.14	1.51	n.s.	0.14	1.50	n.s.
2D:4D	-0.21	-2.30	< 0.05	-0.10	-1.07	n.s.
Age	0.14	1.51	n.s.	0.16	1.69	n.s.
Standing Broad Jump [m]						
BMI	0.02	0.21	n.s.	0.02	0.21	n.s.
Height	0.15	1.66	n.s.	0.15	1.64	n.s.
2D:4D	-0.14	-1.57	n.s.	-0.09	-0.93	n.s.
Age	-0.09	-0.94	n.s.	-0.08	-0.81	n.s.
Handgrip strength right hand [kG]						
BMI	0.40	5.20	< 0.001	0.40	5.11	< 0.001
Height	0.40	5.16	< 0.001	0.40	5.18	< 0.001
2D:4D	-0.07	-0.92	n.s.	0.01	0.11	n.s.
Age	0.03	0.42	n.s.	0.04	0.52	n.s.
Handgrip strength left hand [kG]						
BMI	0.39	5.24	< 0.001	0.38	5.08	< 0.001
Height	0.44	5.85	< 0.001	0.44	5.77	< 0.001
2D:4D	-0.17	-2.27	< 0.05	-0.06	-0.73	n.s.
Age	0.04	0.59	n.s.	0.06	0.78	n.s.
Sit-and-Reach [cm]						
BMI	0.08	0.81	n.s.	0.08	0.83	n.s.
Height	-0.05	-0.54	n.s.	-0.05	-0.56	n.s.
2D:4D	0.03	0.31	n.s.	-0.01	-0.06	n.s.
Age	-0.07	-0.72	n.s.	-0.07	-0.76	n.s.
Flamingo Balance Test [n]						
BMI	0.14	1.53	n.s.	0.14	1.53	n.s.
Height	-0.06	-0.59	n.s.	-0.05	-0.58	n.s.
2D:4D	0.12	1.28	n.s.	0.07	0.70	n.s.
Age	-0.05	-0.55	n.s.	-0.06	-0.66	n.s.

balance (either by falling off the beam or letting go off the foot being held). Number of falls in 60 seconds was counted. If there are more than 15 falls in the first 30 seconds, the test is terminated and a score of zero is given.

Handgrip Strength (HGS): The participant held the dynamometer in the hand to be tested, with the arm held at right angles and the elbow kept by the side of the body. The base of the instrument rested on first metacarpal, while the handle on middle of four fingers. The subject squeezed the dynamometer with maximum isometric effort for about 5 seconds. No other body movement was allowed. The test was repeated twice for each hand and the better result was recorded for each hand.

Descriptive statistics were calculated for results of all tests and age, height, weight and BMI. Relationship between respective test's results and 2D:4D ratio, allowing for age, height and BMI was assessed by the multiple linear regressions. Separate analysis was done for each test and right and left hands DR. The results were also presented on graphs. All calculations were done using Statistica 13.0²⁷.

Results

The mean age of participants were 20.4 years (SD = 1.6). Table 1 shows the descriptive statistics of all the fitness tests and anthropometric measures describing body size. A significant correlation between height and BMI and some of the physical fitness tests were found (for HGSs $r = 0.41$ and $r = 0.46$ $p < 0.001$, for right and left hand respectively). Therefore these two measures, and additionally, age were incorporated into analysis. Results of multiple linear regressions are presented in Table 2. The left hand 2D:4D did not show any association with results of physical fitness tests. However, the right hand 2D:4D showed significant associations with results of 1000 meters run, 5x10 meters shuttle run and left hand grip strength (HGS). All effects were rather low and had different directions. The higher was the 2D:4D ratio of right hand the longer time was required to pass 1000 meters distance. The shorter was the time of 5x10 shuttle run the higher was the 2D:4D of right hand. Finally, the weaker was the left HGS the higher was the 2D:4D of right hand.

Discussion and Conclusion

The present study investigated whether fitness measures, as assessed by Eurofit test battery, had any association with 2D:4D among young adult Polish males. It revealed rather weak relationship between 2D:4D of right hand and results of physical fitness tests. Nevertheless, the smaller was the 2D:4D, the better was the result of endurance and strength tests. This finding was in accord with reports by other studies, indicating that individuals with smaller 2D:4D tend to perform better in these aspects of physical ability. However, we also found an opposite relationship with the results to agility tests. Male students with higher 2D:4D scored better in 5x10 meters

shuttle run, i.e. they needed lesser time to finish running. This finding did not match with results reported by other researchers.

Recently, Ranson et al.²³ examined the correlation between 2D:4D and results of physical fitness test (Eurofit tests)²¹ among 1776 school children aged 7-12 years. After controlling for influence of age and BMI, the authors noted significant relationship between 2D:4D and four performance variables in 899 boys. In comparison to boys with higher right hand's 2D:4D, the low 2D:4D boys ran faster in the 10 x 5 m, finished more runs in the 20 meter shuttle run and had stronger HGS. Our findings partly supported those results, as for HGS, but were in contradictions with that of 10 x 5 m shuttle run, i.e. higher 2D:4D was associated with better performance. Based on the meta-analysis on 2D:4D and athletic prowess including more than 25 samples of males aged 13-31 years Hönekopp and Schuster¹⁶ demonstrated evidence for reliable negative relationship of between 2D:4D and running performance in both sexes ($r \approx -0.26$; $p < 0.001$) and this relationship became stronger as running distance increased. Other study among male teenagers, aged 17.2 year on an average, provided further support for negative correlation between 2D:4D and physical fitness; boys with lower 2D:4D boys showed higher composite measure of physical fitness⁴. Those findings are in accord with previous reports on 2D:4D and performance in soccer, running, and skiing^{3,28,29}. However, positive correlations between right hand and left 2D:4D and 2000 meter rowing time among young adult males were also reported³⁰. The negative association between 2D:4D and physical performance has been almost universal and recently confirmed in members of Han and Hani ethnic groups in China. In both these ethnic groups males with low 2D:4D in right hand had stronger handgrip in both hands^{15,31}.

All reported findings and partially, our data supported the possibility that an association between low 2D:4D and sport and athletic achievement and also physical performances were due to, at least in part, the action of prenatal testosterone¹⁶. It seems that in all those sporting disciplines aerobic efficiency is the most important characteristic, and it depends upon well-developed cardiovascular system³⁰. It was also postulated that prenatal androgen exposure might enhance development of the cardiovascular system³². Early-life androgen exposure might promote the generation of muscular strength and development of cardiovascular system. It might also be possible that individuals exposure to higher foetal androgen level tend to engage more eagerly in sport activities during childhood development, which might cause better sport ability and hence better strength and aerobic performance in later life.

The outcome of our study for a 10 x 5 m shuttle run is in contradictions with all other reports for this strength performance test. It was surprising and did not fit with the results of many other previous studies. Some putative explanation could come from the specificity of the studied sample. We have previously showed that, generally military cadets included in the present study had superior

physical fitness and strength to civil course students, except for a 10 x 5 m shuttle run and a standing broad jump, whereas, those two groups of students, military vs. civil, did not differ in height, weight and BMI²⁵. However, those evidences warrant for further confirmatory studies.

Nearly all referred studies have reported much stronger relationship of right -, but not the left -, hand 2D:4D with aerobic and strength performance in males. In order to explain those differences, Zhang et al. (2013) studied relationship between 2D:4D and androgen receptor (AR) CAG and GGN repeat polymorphisms³³. Activity of androgen receptor was higher in fourth than in the second digit, and inactivation of AR decreased the growth of the fourth digit, which caused a higher 2D:4D ratio. The authors, however, did not find any relationship between CAG

/ GGN alleles and the left hand, right hand, right minus left-hand or mean hand 2D:4D ratios³³. Since that was the first study of such kind, those observations required further explanation to confirm the relationship between AR CAG / GGN polymorphisms and the 2D:4D ratios.

In conclusion, this study found evidence for significant relationship with 2D:4D ratio and aerobic and strength performance, lower DRs better results in performances, and with agility, higher DRs better agility, in young adult male student of military course. Our finding generally support previous reports in a case of aerobic and strength performance but is in contradictions with speed and agility performance. It seems that it results from the specificity of the sample of military students.

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TJELESNA PRIPREMLJENOST I OMJER VELIČINE PRSTIJU (2D: 4D) KOD MUŠKIH STUDENATA IZ WROCLAWA, POLJSKA

SAŽETAK

Postoji spolna razlika kod ljudi što se tiče aerobne učinkovitost, fizičke snage i izdržljivosti i spolna razlika je u velikoj mjeri ovisi o diferencijalnoj koncentraciji testosterona u različitim fazama rasta i razvoja, uključujući intrauterinu fazu ili prenatalni rast. Drugo za četvrtu duljine omjer znamenka (2D: 4D) je potencijalni pokazatelj prenatalnog izlaganja testosteronu. Donja 2D: 4D pokazuje veću izloženost prenatalnog testosterona i obrnuto. Muškarci obično imaju nižu 2D: 4D od ženki. Ova studija u presjeku istražuju odnos između fitnessa mjera i 2D: 4D u mladih odraslih poljskih muškaraca. U istraživanju je sudjelovalo 118 poljskih i studentima prvog ciklusa u Općoj Kosciuszko Vojnoj akademiji kopnene vojske u Wrocławu. Njihova srednja (+ SD) dob bila 20,4 (+1.60) godina. Eurofit Test set je bio korišten za procjenu tjelesne kondicije. Osim visine, težine, druga i četvrta znamenka duljine, rukohvat snage je mjereno pomoću uobičajenog izometričkog dinamometra. Studija je pokazala slab odnos između 2D: 4D desne ruke i rezultate fizičke forme testova. Manja je bila 2D: 4D, bolji je rezultat izdržljivosti i snaga testa. Ovaj nalaz je u skladu s izvješćima drugih studija, što pokazuje da su osobe s manjim 2D: 4D imaju bolje performanse u tim aspektima fizičke sposobnosti. Međutim, mi također pronašao suprotan odnos s rezultatima u agility testovima. Studenti s višim 2D: 4D postigao bolji u 5x10 metara shuttle vožnji. Ovo otkriće nije podudaraju s rezultatima u izvješćima drugih studija. Ova studija pokazuje prema mogućnosti da je povezanost između niske 2D: 4D i sport i sportsku postignuća i također fizičkim predstavama su zbog, barem djelomično, djelovanje prenatalnog testosterona. Daljnja istraživanja su potrebna kako bi istražili odnos parametara tjelesne spremne sa znamenkastim omjerom i na kraju s prenatalnim izlaganjem testosteronu.

