Ambient Science, 2020: Vol. 07(Sp1); 339-344
DOI:10.21276/ambi.2020.07.sp1.ta15

Published by: National Cave Research and Protection Organization, India

ambient
SCIENCE
Vol. 7(Sp1):339-344
Year 2020

TECHNOSCIENCE ARTICLE

The Relationship Between Some Physical Performance Parameters and 2D:4D Digit Ratio in Young Athletes

Aydin Ilhan, Eylem Çelik, Halit Egesoy

Department of Sports Sciences, Pamukkale University, Denizli, Turkey

Study Area: Denizli, Turkey
Coordinates: 37°46′N; 29°05′E

Key words: Physical Fitness, Hormonal differences, Athletic performance

Abstract

A total of 179 male athletes who train regularly in different branches voluntarily participated in this study. It was implemented the tests of ages, length, weight, body mass index, body fat percentage, length of 2nd and 4th fingers of the right and left, vertical jump, curl-up and push-up in 30 sec, handgrip strengths, flexibility, and 20 m sprint to subjects attended to this study. Analysis of the data was tested with Kolmogorov-Smirnov and normal distribution was determined. There was a positive correlation between 2D:4D digit length of the participants and their age, body weight, height, body mass index, vertical jump, right and left-hand grip strength, sit-ups, push-ups and sprint performances. It can be added that finger ratio as a new measurement method can be added to existing criteria for the selection of talented athletes. Hormone and branch-specific evaluations are also thought to be more useful for the selection of qualified athletes who can achieve sporting success in the future.

Introduction:

In today's world, developments in science and technology are increasing rapidly and this development helps to determine the different characteristics of people. Uncovering and knowing the characteristics of people can give us important clues about which sports branches that people will be more suitable for and even more successful. Recently, the length and ratio of people's index and ring fingers and its relation to sportive performance have attracted the attention of scientists and many studies have been conducted on this subject.

In the literature, the ratio of 2nd and 4th (2D: 4D) fingers is described as the ratio of the length of the index finger (2D) to the length of the ring finger (4D) (Celenk, 2011). The difference in length between the index finger (2D) and the ring finger (4D) differs in men and women. The 2nd finger in males is usually shorter than the 4th finger. In women, the 2nd finger is usually equal to the 4th finger or longer than the 4th finger. In the literature, a 2D expression is used for the index finger and 4D expression for the ring finger. Here the letter d stands for the initial letter of the word digit (finger). In the relevant literature, this concept is explained as 2D: 4D finger ratio (Putz *et al.*, 2004; Bennett *et al.*, 2010; Kociuba *et al.*, 2017).

When the literature on the subject is examined, it has been determined that there are important relationships between the success and skill levels of the athletes and the low 2nd and 4th finger ratios of the right and left hands (Manning & Taylor, 2001; Pokrywka *et al.*, 2006; Tester & Campbell, 2007). It has been determined that athletes with a lower 2D:4D finger ratio have higher performance levels in some branches. (Manning *et al.*, 2003; Putz *et al.*, 2004; Paul *et al.*, 2006; Voracek *et al.*, 2006; Manning *et al.*, 2007). It has been stated that low 2D:4D finger ratio in athletes may occur due to exposure to testosterone hormone in the first trimester (the first 12 weeks of pregnancy), and high 2D:4D finger ratio may occur due to relatively high exposure to the estrogen hormone (Manning, 2008). Testosterone has many extragenital developmental effects (Voracek *et al.*, 2010). High fetal androgen levels in humans contribute to the development of their characteristics such as cardiovascular system, visual abilities, physical endurance and speed (Manning & Taylor, 2001). It is stated that the 2D:4D finger ratio of athletes can be used as a criterion in predicting potential sports ability of, especially young athletes (Paul *et al.*, 2006). The aim of this study is to investigate the relationship between 2D:4D hand finger ratio and some physical performance parameters in young athletes.

Methodology:

In this study, the cross-sectional and descriptive method

*Corresponding Author: *trainertennis@hotmail.com*

Ambient Science, 2020: Vol. 07(Sp1); 339-344
DOI:10.21276/ambi.2020.07.sp1.ta15

was used. The sample group of the study consisted of 179 volunteer male athletes aged 10-14 who actively trained in different branches (basketball, tennis, football, swimming) at least three days a week and 6 hours a week. Participants who met the inclusion criteria were invited to Pamukkale University Sports Performance Laboratory and their measurements within the scope of the research were carried out. For the research, Pamukkale University Non-Interventional Research Ethics Committee was discussed at the committee meeting dated 03.03.2020 and numbered 05 and the ethics committee permission was obtained. The content of the study was explained verbally and in writing to the participants who accepted to participate in the study, all questions of the individuals were answered, and signed consent was obtained from the participants. Participants were informed that they had the right to leave the study at any stage of the study.

Research Inclusion Criteria:

- Signing the voluntary basis and consent form.
- Having at least 2 years of training age in the relevant branch.
- Not having an injury for the last 3 months.

Data Collection Tools:

Height: Seca (Germany) brand portable height measuring device was used for height measurement. The height of the subjects; The measurement was recorded as 'cm' after the position was taken in anatomical posture, bare foot, with heels combined, head in the frontal plane, with the head plate touching the vertex point.

Body weight: its measurements were taken with a digital measuring device (Seca, Germany). Body weights of the subjects; 'kg' was measured while in the appropriate sportswear, bare feet and anatomical posture position. In the measurements, the weight of the clothes on the persons was accepted as 0.5 kg as standard.

Body Fat Percentage: it was measured with a Tanita BC-418 brand device. Measurements were made approximately 2-3 hours after breakfast. Caffeine etc. the day before. It was informed that stimulants should not be used. Participants were measured without shoes and wearing the lightest sporty clothing possible.

Flexibility Measurement: it was carried out using the Takei brand "Digital Flexion Meter" device, using the stop and reach test (Fig.-1). This test is used to determine the flexibility of the back and leg area (Holt *et al.*, 1999) and is a test method whose validity and reliability have been studied (Perret *et al.*, 2001).

Figure 1. Stand and Reach Test

Active and Squat Jump: the splash tests were carried out with the Smart speed device of the Fusion Sports brand. In active-jumping, the participants were asked to jump to the highest possible level without waiting by landing in the squat position with their hands on their hips. In squat jumping, the participants were asked to descend to the squat position with their hands on their hips and jump to the highest possible level after waiting in this position for the second (Lockie *et al.*, 2017).

Hand Grip Force: participants squeezed the adjustable handgrip dynamometer with maximum force in a straight direction with their feet and arms at an angle of 45 degrees to their bodies. The best value was recorded in kg at the end of 2 trials performed by giving adequate rest intervals (Gunay *et al.*, 2010).

Maximum Push-Up Test: the metronome is set to 40 beats per minute. With each metronome sound, the participant performed the up or down part of the push-up movement. The participant did as many push-ups as he could, provided that he provided the ideal push-up position shown previously, and the highest score was recorded (Riebe *et al.*, 2018).

Maximum Sit-Up Test: the participants waited in a supine position with their knees bent and their fingertips extended towards their feet. Starting from the point where the fingertips reach, the tape was pulled on both sides to create a gap of 12 cm. The metronome is set to 40 beats per minute, each metronome voice the individual performed the up or down part of the sit-ups movement. The fingertips of the individual completed the 12-centimetre gap while rising (Riebe *et al.*, 2018).

20 Meters Speed: this test was carried out with the Smart speed device of the Fusion Sport brand. After sufficient warm-up, the participants performed a 20-meter maximum speed run with two standing positions. An average of 3 minutes of rest time was given between measurements. The best score was accepted as the participant's value.

2nd and 4th Finger Length Measurement and Ratio: the lengths of the fingers of the participants on the right and left hands (2d & 4d) were measured with a digital calliper (MAC Allister 150mm) that can measure up to 0.01mm from the anatomical boundaries (boneless) from the basal fold of the 2nd and 4th fingers in the palm to the tip of the finger bone (Fig-1). 2D:4D ratios were calculated separately for each hand. The second finger length is divided by the fourth finger length to determine the ratio (Manning & Taylor, 2001).

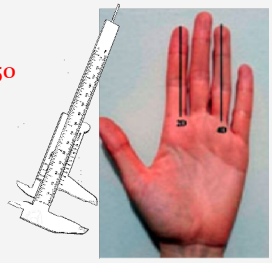

Figure-2. Mac Allister Digital Caliper (150 mm) 2nd and 4th Finger length measurement

Data Analysis: all data are expressed as mean ± standard deviation. The normality

Ambient Science, 2020: Vol. 07(Sp1); 339-344
DOI:10.21276/ambi.2020.07.sp1.ta15

distribution of the data was interpreted through the Kolmogorov-Smirnov test and the skewness-kurtosis values between -2 and +2, and the data were found to be normally distributed. To control the relationship between variables, Pearson correlation analysis was used, and One-Way Anova Analysis of Variance was used to understand whether there was a significant difference between finger length, finger ratio and physical performance values between four diffrent sports branches. For all statistical methods the level of error (α) was accepted as 0.05.

Result:

Shows the minimum, maximum, average, and standard deviation values of all the characteristics of the athletes who participated in the study (basketball, football, tennis and swimming) (Table.1).

As per the One-Way Anova Analysis results in which finger lengths were compared according to branches in Table 2, it was determined that the 2D and 4D lengths of the right and left hand of tennis players were statistically significantly shorter than the swimmers in all parameters ($p < 0.05$) (Table.2).

The results of the Pearson Correlation Analysis between finger length measurements and 2D: 4D finger ratio values of all athletes and sportive performance parameters are given in Table 3. It was observed that there was a positive correlation between right and left-hand 2D and 4D finger lengths of the participants and their age, body weight, height, body mass index, active and squat jump, right and left-hand grip strength, shuttle, push-up and speed performances ($p < 0.05$) (Table-3).

Table 2. Comparison of Finger Lengths According to Branches

Variable	Mean	Sd	Variable	Mean	Sd	Difference
Right Hand 2D Length (cm) (F=5.59; p= 0.00*)						
Basketball	6.67	0.68	Tennis	6.12	0.46	B-ball-Ten;p<0.01
Football	6.46	0.65	Swimming	6.78	0.72	Ten-Swim.p<0.00
Right Hand 4D Length (cm) (F=5.57; p= 0.00*)						
Basketball	6.69	0.69	Tennis	6.19	0.45	B-ball-Ten;p<0.03
Football	6.58	0.65	Swimming	6.89	0.7	Ten.-Swim; p<0.00
Left Hand 2D Length (cm) (F=4.84; p=0.00*)						
Basketball	6.58	0.67	Tennis	6.07	0.47	B-ball-Ten.; p<0.02
Football	6.5	0.65	Swimming	6.72	0.7	Ten.-Swim; p<0.00
Left Hand 4D Length (cm) (F=3.93; p=0.01*)						
Basketball	6.71	0.75	Tennis	6.23	0.54	Ten.-Swim.; p<0.01
Football	6.61	0.72	Swimming	6.88	0.78	
Right Hand 2D:4D Ratio (F=1.62; p=0.19)						
Basketball	1	0.03	Tennis	0.99	0.04	
Football	0.98	0.04	Swimming	0.98	0.03	
Left Hand 2D:4D Ratio (F=0.30; p=0.82)						
Basketball	0.98	0.05	Tennis	0.98	0.05	
Football	0.99	0.05	Swimming	0.98	0.04	

Discussion :

This study was conducted to investigate the relationship between 2D:4D hand finger ratio and some physical performance parameters in young athletes. In this study, a positive correlation was found between the 2D and 4D finger lengths of the participants' right and left hand and their age, body weight, height, body mass index, active and squat jump, right and left-hand grip strength, sit-up, push-up and speed performances. In addition, considering the branch variables, it was determined that the right and left-hand 2D and 4D finger lengths of tennis players were statistically significantly shorter than the swimmers in all parameters. There are studies that are similar to current research results. Between right and left hand 2D-4D finger lengths of athletes and age, body weight, height, body mass index, percentage of body fat, vertical jump, right-hand grip strength, left-hand grip strength, back-leg strength and flexibility parameters in a positive direction and VO2 max. Bilgiç *et al*. (2016) found a negative relationship with the parameter. Gul (2018) reported a significant relationship between tennis players' left and right-hand 2D:4D finger ratios and height, body weight, handgrip and arm strength and aerobic performance parameters (Gul, 2018). In addition, Ranson *et al*. (2015) and Wang *et al*. (2016), reported a significant relationship between 2D: 4D finger ratios of the participants and their strength, endurance and speed values. Gunay *et al*. (2017) reported significant differences between swimmers and sedentary individuals in terms of the 2D:4D ratio of the right hand, and also between the groups when the 2D:4D ratios of female swimmers and sedentary individuals were compared. Pokrywka *et al*. (2006), found the ratio of 2D:4D of elite and non-elite female athletes was low and it was assumed that this could be a positive indicator of sports potential in women. Bennett *et al*. (2010) found that rugby athletes had a low 2D:4D finger ratio and reported a positive correlation between athletes' low 2D:4D finger ratio and their high performance. Bennett *et al*. (2010) found that rugby athletes had a low 2D:4D finger ratio and reported a positive correlation between athletes' low 2D:4D finger ratio and their high performance.

On the other hand, there are studies that are not similar to the existing research in the literature. Eghbali, (2016) found no significant relationship between 2D: 4D finger ratios on boys aged 7-13 and their strength, endurance, speed, agility and flexibility. Baskaya *et al*. (2018) reported a negative relationship between right and left-hand 2D:4D ratio and 10m-20m speed and agility values in their study on girls and boys aged 8-10. Ranson *et al*. (2015) reported a significant and negative relationship between 2D:4D finger ratio of male athletes and aerobic capacity, handgrip strength and agility. Ozen *et al*. (2019) reported no significant relationship between swimming athletes' right-hand 2D:4D finger ratio and their swimming performance. In addition, it has been stated that there was a negative relationship between the swimming degrees of the athletes and the average body mass index values. Further, a negative relationship between the swimming degrees of the athletes

Ambient Science, 2020: Vol. 07(Sp1); 339-344
DOI:10.21276/ambi.2020.07.sp1.ta15

Table 1. Descriptive Statistics Table for Branches

Basketball (n = 47)	Min	Max	Mean	Sd	Tennis (n= 21)	Min	Max	Mean	Sd
Age (years)	7.00	15.00	12.21	1.76		11.00	16.00	12.38	1.32
Height (cm)	117.60	178.20	152.86	13.97		141.20	169.00	155.68	8.21
Body Weight (kg)	20.40	78.70	45.32	13.09		29.20	58.40	45.94	7.89
Body Mass Index (kg / m2)	12.20	32.30	18.98	3.90		13.80	23.40	18.99	2.76
Body Fat Percentage	5.50	39.80	16.45	7.61		4.60	27.90	15.80	7.58
Right Hand 2D Length (cm)	5.00	7.80	6.67	0.68		5.20	7.00	6.12	0.46
Right Hand 4D Length (cm)	5.10	7.90	6.69	0.69		5.20	7.00	6.19	0.45
Left Hand 2D Length (cm)	5.00	7.70	6.58	0.67		5.10	7.00	6.07	0.47
Left Hand 4D Length (cm)	5.10	8.80	6.71	0.75		5.20	7.30	6.23	0.54
Right Hand 2D:4D Ratio	0.94	1.08	1.00	0.03		0.90	1.07	0.99	0.04
Left Hand 2D:4D Ratio	0.68	1.07	0.98	0.05		0.91	1.07	0.98	0.05
Flexibility (cm)	-18.40	16.50	-1.76	9.37		-13.60	10.00	0.64	6.59
Active Jump (cm)	10.81	38.04	22.45	5.75		20.70	42.90	29.62	5.80
Squat Jump (cm)	9.82	41.39	22.20	6.00		20.50	35.60	26.57	4.45
Right Hand Grip Strength (kg)	7.30	41.30	19.39	7.16		9.10	33.20	21.86	5.35
Left Hand Grip Strength (kg)	6.60	35.60	18.43	6.56		10.50	30.60	19.00	4.87
Push-Up (pieces)	0.00	26.00	9.87	5.71		1.00	25.00	11.24	6.32
Sit-Up (pcs)	2.00	75.00	29.85	18.84		5.00	138.00	38.43	25.98
20m Sprint (sec)	3.45	5.61	4.25	0.43		3.22	4.72	3.84	0.39
Football (n = 62)	**Min**	**Max**	**Mean**	**Sd**	**Swimming (n = 49)**	**Min**	**Max**	**Mean**	**Sd**
Age (years)	10.00	15.00	11.90	1.53		9.00	18.00	13.00	2.52
Height (cm)	124.00	177.00	151.43	12.92		136.60	186.70	157.60	13.73
Body Weight (kg)	20.30	79.10	42.04	12.24		29.90	90.80	48.90	14.08
Body Mass Index (kg / m2)	1.40	30.10	17.94	3.72		10.00	24.00	15.17	5.91
Body Fat Percentage	5.90	33.90	14.08	5.88		6.20	31.60	15.19	6.05
Right Hand 2D Length (cm)	4.60	7.70	6.46	0.65		5.10	8.00	6.78	0.72
Right Hand 4D Length (cm)	5.10	7.90	6.58	0.65		5.80	8.30	6.89	0.70
Left Hand 2D Length (cm)	4.90	7.80	6.50	0.65		5.50	8.20	6.72	0.70
Left Hand 4D Length (cm)	5.10	8.20	6.61	0.72		5.60	8.50	6.88	0.78
Right Hand 2D:4D Ratio	0.90	1.09	0.98	0.04		0.88	1.06	0.98	0.03
Left Hand 2D:4D Ratio	0.91	1.16	0.99	0.05		0.87	1.11	0.98	0.04
Flexibility (cm)	-11.20	17.60	1.39	6.55		-15.80	20.20	2.62	8.55
Active Jump (cm)	3.40	43.00	23.63	7.46		15.50	36.96	24.27	5.57
Squat Jump (cm)	14.80	36.00	25.00	4.72		9.50	35.49	23.63	5.54
Right Hand Grip Strength (kg)	9.50	37.40	19.07	6.34		12.90	41.00	22.59	8.71
Left Hand Grip Strength (kg)	9.60	37.60	18.85	6.58		9.90	45.50	21.17	8.51
Push-Up (pieces)	2.00	35.00	13.45	6.91		6.00	45.00	18.60	10.22
Sit-Up (pcs)	9.00	75.00	45.55	22.37		10.00	85.00	54.00	22.38
20m Sprint (sec)	2.36	4.70	3.51	0.35		3.43	5.52	4.12	0.47

Table-3: Relationship Between Finger Lengths and Sportive Performance Parameters

		a	b	c	d	e	f	g	h	I	j	k	l	m
Right Hand 2D Length (cm)	r	0.68	0.78	0.66	0.20	-0.08	0.12	0.21	0.24	0.68	0.70	0.21	0.29	-0.21
	p	0.00*	0.00*	0.00*	0.02*	0.30	0.12	0.01*	0.00*	0.00*	0.00*	0.01*	0.00*	0.01*
Right Hand 4D Length (cm)	r	0.69	0.79	0.68	0.20	-0.08	0.13	0.23	0.27	0.70	0.72	0.22	0.31	-0.25
	p	0.00*	0.00*	0.00*	0.02*	0.28	0.10	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Left Hand 2D Length (cm)	r	0.70	0.79	0.69	0.24	-0.06	0.13	0.25	0.27	0.70	0.73	0.22	0.28	-0.27
	p	0.00*	0.00*	0.00*	0.00*	0.43	0.08	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
Left Hand 4D Length (cm)	r	0.69	0.79	0.66	0.18	-0.10	0.08	0.28	0.27	0.69	0.72	0.21	0.34	-0.27
	p	0.00*	0.00*	0.00*	0.03*	0.21	0.27	0.00*	0.00*	0.00*	0.00*	0.01*	0.00*	0.00*
Right Hand 2D:4D Ratio	r	0.01	0.01	0.00	0.03	0.00	0.00	-0.05	-0.06	-0.04	-0.03	-0.03	-0.03	0.09
	p	0.89	0.92	0.96	0.76	0.96	1.00	0.52	0.42	0.57	0.65	0.74	0.67	0.26
Left Hand 2D:4D Ratio	r	-0.12	-0.13	-0.06	0.09	0.10	0.08	-0.10	-0.04	-0.10	-0.11	0.01	-0.17	0.07
	p	0.12	0.09	0.45	0.32	0.20	0.30	0.19	0.57	0.20	0.17	0.95	0.02	0.34

a-Age (years); b-Height (cm); c-Body Weight (kg); d-Body Mass Index (kg/m2); e-Body Fat Percentage; f- Flexibility (cm); g-Active Jump (cm); h-Squat Jump (cm); i-Right Hand Grip Strength (kg); j-Left Hand Grip Strength (kg); k-Push-Up (pieces); l-Sit-Up (pcs); m-20m Sprint (sec) *p<0.05

Ambient Science, 2020: Vol. 07(Sp1); 339-344
DOI:10.21276/ambi.2020.07.sp1.ta15

and the average body mass index values.

Studies evidenced that there are important relationships between the success and skill levels of athletes and low 2D:4D finger ratios of the right and left hands (Manning & Taylor, 2001; Putz *et al*., 2004; Pokrywka *et al*., 2006; Tester & Campbell 2007). Aksu *et al*., (2009) and Manning & Taylor, (2001) reported in their study that there was a negative correlation between 2D:4D finger ratio and testosterone levels in the blood of the participants. Manning *et al*. (2002) and Honekopp *et al*. (2006) reported in their similar studies that there was a direct proportion between index finger length and estrogen hormone height, ring finger length and testosterone hormone height. Manning, (2002) reported that skiers with higher testosterone values compared to 2D:4D finger ratios performed better during the competition. Manning *et al*., (2007) reported that high testosterone level of long-distance athletes had better grades than low athletes. Also, Paul *et al.* (2006) reported that athletic success is higher in female athletes where testosterone value is dominant with low 2D:4D finger ratio and low 2D:4D finger ratio can be used to reveal the potential abilities of athletes. It is stated that the difference in length between the index finger (2D) and ring finger (4D) differs between men and women. In many studies, it is stated that the ratio of 2D:4D is lower in men because the 2nd finger is generally shorter than the 4th finger in men and the 2nd finger is generally equal to or longer than the 4th finger in women (Manning, 2002; Honekopp *et al*., 2006; Martin *et al*., 2008; Honekopp & Watson, 2010; Perciavalle *et al*., 2014; Hsu *et al*., 2015). In a meta-analysis study conducted by Honekopp & Watson (2010), it was stated that right-hand 2D:4D ratio of athletes may be a better indicator in terms of morphological, physiological, psychological and behavioral characteristics compared to left-hand 2D:4D ratio (Honekopp & Watson, 2010). Hsu *et al*. (2015) reported that elite tennis athletes had a lower 2D:4D ratio in their right hand than non-elite athletes, and the coaches could use this value as a valid indicator in talent screening of tennis players. Besides, Martin *et al*. (2008) stated that the left hand of men and the right hand of women have a greater 2D:4D ratio.

In conclusion, although it is supported by our findings that there is a relationship between 4d finger length, which expresses the dominance of testosterone hormone in humans, and the performance of athletes, there are studies showing that there is no relationship in the literature. From this point of view, it is a fact that multi-subject and repetitive researches are needed to form clearer opinions about the subject. It is thought that this study can be added to the existing criteria for the selection of talented athletes as a new measurement method, and it will be more useful for selecting qualified athletes who can achieve sportive success in the future by making hormone and branch-specific evaluations.

Acknowledgment:

The Authors thank to personnel and players of the Yildizlar Sport Club, FenerbahceDenizli Soccer School, Pamukkale Tennis Club and Pamukkale University Swimming Club for their assistance and cooperation.

References:

Aksu, F., Topaçoğlu, H., Arman, C., Ataç, A. & Tetik, S. (2009): Neck circumference and 2:4digit ratio in patients with acute myocardial ınfarction. *Turkey Clinics J. Cardio. VascSci.*, (21):147-152.

Baskaya, G., Ersoy, A. & Karavelioglu, M.B. (2018): Investigation of the relationship between 2d:4d finger ratios of children aged 8-10 years and some motoric characteristics. *Nigde Univers. J. Phys. Edu. Sport Sci*., 12(2):90-98.

Bennett, M., Manning, J.T., Cook, C.J. & KIlduff, L.P. (2010): Digit ratio (2D:4D) and performance in elite rugby players. *J. Sports Sci*., 28(13):1415–1421.

Celenk, C. (2011): The relationship of the ratio of 2nd and 4th (2d: 4d) fingers of elite athletes in different branches with some biochemical and endocrinological parameters affecting sports performance. Gazi University, Faculty of Health Sciences, PhD Thesis, Ankara.

Gul, I. (2018): Investigation of the effect of 2d: 4d finger length and ratio on tennis performance. Master Thesis, AU Institute of Social Sciences, Amasya.

Gunay, M., Tamer, K. & Cicioglu, I. (2010): **Sports Physiology and Performance Measurement**. Pub. by: Gazi Bookstore.

Gunay, E., Aksu, F.T., Çelik, A., & Mas, N.(2017): Digit ratio (2D:4D) comparison between competitive age group swimmers and non-athletes. *Civil. Sport*., 18(4):206–209.

Holt, L.E., Pelham, T.W. & Burke, D.G. (1999): Modifications to the Standard Sit-and-Reach Flexibility Protocol. *J. Athl. Train*., 34(1):43-47.

Honekopp, J., Manning, J.T. & Muller, C. (2006): Digit ratio (2D:4D) and physical fitness in males and females: Evidence for effects of prenatal androgens on sexually selected traits. *Hormones Behav.*, 49:545–549.

Honekopp, J. & Watson, S. (2010): Meta-analysis of digit ratio 2D:4D shows greater sex difference in the right hand. *Am. J. Human Biol.*, 22(5):619-630.

Hsu, C-C., Su, B., Kan, N-W., Lai, S-L., Fong, T-H., Chi, C-P., Chang, C-C. & Hsu, M-C. (2015): Elite collegiate tennis athletes have lower 2d-4d ratios than those of nonathlete controls. *J. Strength Cond. Res*., 29(3):822–825.

Kociuba, M., Koziel, S., Chakraborty, R. & Ignasiak, Z. (2017): Humans exhibit sex differences in competitiveness, sensation-seeking and risk-taking attitude, which are required in sports. *J. Biosoc. Sci.*, 49(5): 623-633.

Lockie, R.G, Moreno, M.R, Orjalo, A.J. Stage, A.A., Liu, T.M., Birmingham-Babauta, S.A., Hurley, H.M., Torne, I.A., Beiley, M.D., Risso, F.G., Davis, D.L., Lazar, A., Stokes, J.J., Giuliano, D.V. (2019): Repeated-Sprint Ability in Division I Collegiate Male Soccer Players: Positional Differences and Relationships with Performance Tests. *J. Strength Cond. Res.*, 33(5):1362-1370.

Manning JT, Taylor RP. (2001). Second to fourth digit ratio and male ability in sport: implications for sexual selection in humans. *Evol. Hum. Behav.*, (22):61–69.

Manning, J.T., Martin, S., Trivers, R.L. & Soler, M. (2002): 2nd to 4th digit ratio and offspring sex ratio. *J. Theor. Biol*, 21(7):93–95.

Manning, J.T. (2002): The ratio of 2nd to 4th digit length and performance in skiing. *J. Sports Med. Phys. Fit*., (42):446-450.

Manning, J.T., Bundred, P.E. & Taylor, R. (2003): The ratio of 2nd and 4th digit length: A prenatal correlate of ability in sport, p-165–174. In: **Kinanthropometry**. Reilly, T & Marfell-Jones, M, eds. Pub. by: Routledge, Taylor and Francis Group, London.

Manning, J.T., Morris, L. & Caswell, N. (2007): Endurance running and digit ratio (2D:4D): implications for fetal testosterone effects on running speed and vascular health. *Am. J. Hum, Biol.*, (19):416–421.

Manning, J.T. (2008): **Finger Ratio**. Pub. by: Faber & Faber, London.

Martin, J.T., Puts, D.A. & Breedlove, S.M. (2008): Hand asymmetry in heterosexual and homosexual men and women: relationship to 2D:4D digit ratios and other sexually dimorphic anatomical traits. *Arc. Sex. Behav.*, (37):119-132.

Ozen, G., Atar, O. & Koc, H. (2019): Digit ratio (2D:4D): relationship with freestyle swimming performance of adolescent well-trained swimmers. *J. Pedag. Psychol*., (2):150-154.

Paul, S.N., Kato, B.S., Hunkin, J.L., Vivekanandan, S. & Spector, T.D. (2006): The big finger-the second to fourth digit ratio (2D:4D) is a predictor of sporting ability in females. *Br. J. Sports Med*., (40):981–983.

Perret, C., Poiraudeau, S., Fermanian, J., Colau, M.M., Benhamou, M.A. & Revel, M. (2001). Validity, reliability, and responsiveness of the fingertip-to-floor test. *Arch. Phys. Med. Rehabil.*, 82(11):1566-1570.

Pokrywka, L., Rachon, D., Sucheka-Rachon, K. & Bitel, L. (2006). The second to fourth digit ratio in elite and non-elite female athletes. *Am. J. Human Biol*., (17):796–800.

Putz, D.A., Gaulin, S.J.C, Sporter, R.J. & McBurney, D.H. (2004). Sex hormones and finger length. What does 2D:4D indicate? *Evol. Human Behav*., (25):182–199.

Ranson, R., Strattonb, G. & Taylor, S.R. (2015): Digit ratio (2D:4D) and physical fitness (Eurofit test battery) in school children. *Early Human Develop*., (91):327-331.

Riebe, D., Ehrman, J.K., Liguori, G. & Magal, M. (2018): **ACSM's Guidelines for Exercise Testing and Prescription**. Pub. by: Wolters Kluwer.

Tester, N. & Campbell, A. (2007): Sporting achievement: what is the contribution of digit ratio? *J. Pers*., (75):663–677.

Wang, Y., Wang, H.L, Li, Y.H., Zhu, F–L., Li, S–J. & Ni, H. (2016): Using 2D: 4D digit ratios to determine motor skills in children. *Eur. Rev. Med. Pharmacol. Sci.*, 20(5):806-809.

Voracek, M., Reimer, B., Ertl, C. & Dressler, S.G. (2006): Digit Ratio (2D:4D), Lateral Preferences and Performance in Fencing. *Pepcept. Mot. Skills*, 103(2):427-446.

Voracek, M., Reimer, B. & Dressler, S.G. (2010): Digit ratio (2D:4D) predicts sporting success among female fencers independent from physical, experience, and personality factors. *Scand. J. Med. Sci. Sports*, (20):853–860.