

## The Relationship Between Physical Fitness Levels and Digit Ratio (2D:4D) of High School Students Engaged Actively in Sports

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### Abstract

The aim of this study is to examine the association between physical fitness and 2D:4D finger ratio of high school students engaged actively in sports. 23 licensed male athletes and 23 sedentary (n=46) high school students participated in the study voluntarily. The participants age, body weight, body mass index, 2D:4D finger measurement values were recorded and 20 meter shuttle run, 30 meter sprint, sit and reach test, standing long jump and hand grip strength tests were applied on the participants. The data obtained were assessed in SPSS 21 program and the results were assessed at  $p < 0.05$  significance level. While the average age of athletes was  $15.82 \pm 1.11$  years, the average age of sedentary group was  $15.13 \pm 0.96$  years. While statistically significant difference was found between sedentary and athlete groups in terms of  $VO_2\max$ , right and left hand grip strength and long jump average values ( $p < 0.05$ ), no statistically significant difference was found between speed and flexibility measurement results ( $p > 0.05$ ). When the 2D:4D averages of sedentary and athlete groups were compared, statistically significant difference was found between right hand averages ( $p < 0.05$ ). When right and left hand 2D:4D was compared, no statistically significant difference was found in sedentary group ( $p > 0.05$ ), while significant difference was found in athletes ( $p < 0.05$ ). Statistically significant difference was found between 2D:4D averages of both hands with all physical fitness parameters ( $p < 0.05$ ). In the present study, finger ratio of the groups were found to be associated with some motoric and functional dominance parameters.

**Keywords:** digit ratio, 2D:4D, physical fitness, high school student

### 1. Introduction

Physical fitness includes cardiorespiratory endurance, muscular endurance, muscular force, muscle strength, speed, flexibility, balance, reaction time and body composition (Özer, 2001). For this reason, physical fitness cannot be assessed by a single test and consists of multiple distinct aspects such as balance, flexibility, speed of limb movement, sprinting speed, endurance and static, explosive, functional, and trunk strength as is evidenced by factor analyses e.g. (Simons et al., 1990). Determination of physical fitness levels is possible especially through sportive achievement skills reaching the top level. For this reason, talents should be determined especially in early ages and suitable methods should be determined to find out talented athletes.

Many children strive to attain excellence in sport. However, although talent identification and development programs have gained popularity in recent decades, there remains a lack of consensus in relation to how talent should be defined or identified and there is no uniformly accepted theoretical framework to guide current practices (Vaeyens et al., 2008). In addition, it is possible to speak of the lack of talent identification practices especially for school children. New researches and new talent markers on this issue attract researchers' interest. One of these research topics is the association between performance and 2D:4D. A great number of researches have been conducted on this topic led by Manning (Manning et al., 1998); however, it is not yet possible to talk about a standard approach.

2D:4D ratio is the ratio of second digit (index finger (2D)) to the fourth digit (ring finger (4D)) length (Çelenk, 2011). Low 2D:4D ratio is reported to be associated with being exposed to more testosterone hormone in prenatal period, while high 2D:4D ratio is reported to be associated with being exposed to more oestrogen hormone (Lutchmaya et al., 2004; Manning and Fink, 2008; Bennett et al., 2010). Prenatal testosterone is reported to have a negative association with 2D:4D, while prenatal oestrogen is reported to have a positive association with 2D:4D (Manning et al., 1998). In addition, it is thought that there is a negative association between 2D:4D and sportive performance (Manning and Taylor,

2001). Similarly, a great number of studies have shown that 2D:4D ratio has a negative correlation with physical fitness (Manning and Taylor, 2001; Manning, 2002; Pael et al., 2006; Bennett et al., 2010; Longman et al., 2011). In their study, Manning and Taylor (2001) found that 2D:4D ratios of professional football players were significantly lower when compared with the control group. In addition, international athletes were found to have lower 2D:4D ratio when compared with other athletes. Again, a significant negative association was found between 2D:4D and sport activities such as rugby (Bennett et al., 2010), skiing (Manning, 2002), and football (Manning and Taylor, 2001) in terms of performance.

Considering the facts that the ratio of finger lengths to each other are determined in the mother's womb and do not change in adolescence or adulthood (Çelik et al., 2010) and that it is important to identify talent at an early age besides physical fitness in order to reach top level performance, the significance of the association between 2D:4D ratio and athletes' physical fitness levels will be better understood. It is clear that if an association is found between 2D:4D ratio and physical fitness levels, this will provide a new perspective and contribution to studies conducted about talent identification especially in Turkey and to talent identification programs conducted in schools. The aim of this study is to examine the association between physical fitness and 2D:4D finger ratios of high school students engaged actively in sport.

## 2. Method

### 2.1 Participant Characteristics

23 licensed amateur male soccer players and who were attending school teams and 23 sedentary high school students in Samsun participated in the study voluntarily. The participants' body weight was measured with a 0.1 kg precision electronic scale, while their height was measured with a 0.01 cm precision digital stadiometer.

### 2.2 Measures and Tests

#### 2.2.1 Body Mass Index

Body weight / Height (m)<sup>2</sup> formula was used

#### 2.2.2 2D:4D Ratio Measurement

The measurement of the area between the pulp and the basal line on the proximal part of the finger on palmar side of the hand was conducted by using a Vernier caliper that can measure up to 0.05 mm. The measurements were made twice by the same person for reliability and they were expressed in centimetre. In order to find out the ratio, the length of second digit was divided to the length of the fourth digit.

#### 2.2.3 20 Meter Shuttle Run Test

In this test, which starts with a walking tempo and ends with a sprint, the participants were made to reach from one line to another without being late with each beep sound from a 20 m. shuttle run test cd recorded previously in line with the protocol within a 20 meter distance between two lines. In each test area, 4 students were made to run based on similar age, weight and height characteristics. Each time they reached the line, they were made to touch the line. The samples were made to run with a speed in line with the repetition interval of recorded signal sounds and they were motivated to keep running. The runs of participants who were not able to catch the beep sound twice successively were ended. The phase the sample was stopped was recorded as the test result. VO<sub>2</sub>max value was recorded as ml/kg/minute according to the result obtained.

#### 2.2.4 30 Metre Sprint Test

Electronic and telemetric chronometer that can record one hundredth of a second was used to find out 30 meter sprint. The test repeated two times and the best result was recorded

#### 2.2.5 Sit and Reach Test

The upper surface of a 32 cm high and 35 cm long box was divided into centimetres. The participants sat on the floor, stretched their legs and placed the soles of their feet against the box after removing shoes. Later, they reached forward over the box as far as possible from the trunk (waist and hip). The farthest point reached by fingers was measured in cm. and at the end of three repetitions the best degree was taken.

#### 2.2.6 Standing Long Jump

The participants were made to jump from behind the starting line with their arms behind, in squat position with both feet parallel to each other and by moving their arms up to the front. The distance between the starting line and the place where the participant touched the closest to the line was measured in cm. The participants were asked to stand with both feet slightly apart without falling forward or backward. The test was conducted twice and the better value was recorded.

### 2.2.7 Hand Grip Strength

Hand grip strength was measured with Jamar hydraulic dynamometer (Sammons Preston, USA). The measurement was started from the dominant side. The measurement was conducted when the athlete was in sitting position with 90° flexion of the forearm without taking support from the trunk. The measurement was repeated 3 times successively and the average value was used. The values were recorded in kilogram.

### 2.3 Analysis of Data

The obtained data has been evaluated in the SPSS 21 software program. The mean and standard deviations of all data has been calculated; in the determination of the difference between the averages of the athletes and sedentary groups, the Independent Samples T-Test has been used. In the determination of the statistical relationship between physical fitness and 2D:4D, the Pearson Correlation Coefficient analyses have been used.

## 3. Results

In the sedentary group, average age was 15,13 years, average height was 156,65 cm, average weight was 48,39 kg and average BMI was 19,72 kg/m<sup>2</sup>, while the same values were found as 15,82 years, 150,17 cm, 42,21 kg, 18,68 kg/m<sup>2</sup>, respectively in the athlete group.

Table 1. Measurement parameters of the study group

	Group	n	$\bar{x}$	Sd	t	p
Age	Sedentary	23	15,13	,967	-2,261	<b>,029</b>
	Athlete	23	15,82	1,114		
Height (cm)	Sedentary	23	156,65	8,331	2,880	<b>,006</b>
	Athlete	23	150,17	6,853		
Weight (kg)	Sedentary	23	48,39	7,346	3,319	<b>,002</b>
	Athlete	23	42,21	5,062		
BMI (kg/m <sup>2</sup> )	Sedentary	23	19,72	2,652	1,661	,104
	Athlete	23	18,68	1,433		
30 meter (sec)	Sedentary	23	5,40	,351	1,590	,119
	Athlete	23	5,22	,432		
VO <sub>2</sub> max (ml/kg/minute)	Sedentary	23	43,77	4,800	-3,848	<b>,000</b>
	Athlete	23	49,21	4,792		
Grip strength (right)	Sedentary	23	24,56	4,822	-4,421	<b>,000</b>
	Athlete	23	31,21	5,367		
Grip strength (left)	Sedentary	23	24,65	4,696	-3,686	<b>,001</b>
	Athlete	23	29,04	3,254		
Flexibility (cm)	Sedentary	23	19,13	3,034	1,823	,075
	Athlete	23	17,13	4,299	1,823	
Standing long jump (cm)	Sedentary	23	161,21	9,055	-3,666	<b>,001</b>
	Athlete	23	171,13	9,284		
2D:4D right	Sedentary	23	,92	,087	-2,331	<b>,024</b>
	Athlete	23	,86	,070		
2D:4D left	Sedentary	23	,92	,072	,889	,379
	Athlete	23	,93	,063		

**p<0.05**

When sedentary and athlete groups were compared, while statistically significant difference was found between VO<sub>2</sub>max, right and left hand grip strength and long jump average values (p<0.05), no statistically significant difference was found between speed and flexibility measurement results (p>0.05). When 2D4D averages of sedentary and athlete groups were compared, statistically significant difference was found in right hand averages (p<0.05).

Table 2. Comparison of right hand 2D:4D and left hand 2D:4D averages of sedentary and athlete groups

	Parameters	n	$\bar{x}$	sd	t	p
Sedentary	Right hand 2D:4D	23	,92	,087	,085	,933
	Left hand 2D:4D	23	,92	,072		
Athlete	Right hand 2D:4D	23	,86	,070	-3,945	<b>,001</b>
	Left hand 2D:4D	23	,93	,063		

**p<0.05**

No statistically significant difference was found when right hand 2D:4D and left hand 2D:4D of the sedentary group were compared (p>0.05), while statistically significant difference was found in athletes (p<0.05). In the athlete group, right hand 2D:4D ratios are lower than left hand 2D:4D ratios.

Table 3. Comparison of 2D:4D ratios and physical fitness tests of the athlete group

Parameters	n		VO <sub>2</sub> max	30m	Flexibility	Standing long jump	Grip strength	
							Right	Left
Right hand 2D:4D	23	r	-0.206*	-0.104*	0.192*	0.249*	0.281*	0.117*
	23	p	<b>0.011</b>	<b>0.018</b>	<b>0.043</b>	<b>0.022</b>	<b>0.012</b>	<b>0.046</b>
Left hand 2D:4D	23	r	0.52*	-0.03*	-0.043*	0.148*	-0.139*	-0.139*
	23	p	<b>0.001</b>	<b>0.048</b>	<b>0.047</b>	<b>0.038</b>	<b>0.011</b>	<b>0.024</b>

p<0.05

Statistically significant difference was found between 2D:4D averages of both hands with all physical fitness parameters (p<0.05).

#### 4. Discussion

In the present study, associations between participants' physical fitness and 2D:4D ratios were discussed.

In our study, when the sedentary group and athlete group was compared, statistically significant difference was found between VO<sub>2</sub>max, right and left hand grip strength and long jump average values, while no significant difference was found between sprint and flexibility measurement results. At the same time, athletes' grip strength and 30 m. sprint averages, VO<sub>2</sub>max, standing long jump and flexibility values were found to be better than the non-athlete group. In the study athletes 30m. sprint averages 5,22, VO<sub>2</sub>max averages 49,21, right hand grip strength averages 31,21, left hand grip strength averages 29,04, flexibility averages 17,13, standing long jump averages 171,13 was determined. Gümüş and Akalın (2016), was found the dominant hand grasp force of sportsmen 57.6±15.0 for right-handed, 53.5±7.7 for left-handed, these values for nondominant hand were 46.5±12.4 and 47.5±9.2 respectively for national sportsmen. Acar and Tutkun (2017), was found 30 meter sprint (4,99±1,12 and 5,95±1,43 sec), right hand grip (26,3±3,2 and 17,3±1,9 kg), left hand grip 24,0±2,5 and 15,2±2,1 kg. for 14-year-old footballer and sedentary groups respectively. Also they found that grip strength, 30 m. sprint averages and flexibility values of 14-year-old footballers were better when compared with non-athlete groups, while Günay et. al. (2011), found that sit and reach test averages of 13-year-old athletes were found to be better when compared with a sedentary group of the same age group. When hand skill, strength, speed and flexibility average values of active athletes are taken into consideration, it is an expected result for hand related parameters of athletes to be higher than sedentary groups. Eler and Acar (2018), 10-12 year old boys who regularly attended physical education and sports lessons participated in their study (n=240). The students were divided into two groups and the first group had regular rope jump training exercises for 3 days a week for 10 weeks, and the control group only continued physical education and sports lessons. When the measurement differences between pre-test and post-test were compared according to the groups, it was determined that weight, body fat ratio, 20m sprint, maxVO<sub>2</sub> and leg strength measurements were significantly different in favor of rope jump group (p<0.05). According to these results, it can be said that as a result of doing sport, motoric characteristics of children in growth and development periods such as strength, speed and flexibility develop positively.

When 2D:4D averages of sedentary and athlete groups were compared, statistically significant difference was found in right hand averages. Athletes' right hand 2D:4D averages were found as 0.86 and left hand 2D:4D averages were found as 0.93, while sedentary group's right hand 2D:4D averages were found as 0.92 and left hand 2D:4D averages were found as 0.92. In their study, Giffin et al., (2012), found the 2D:4D ratios of varsity athletes as 0.97, while 2D:4D ratios of non-varsity athletes was 0.99 and they reported that varsity athletes had significantly lower ratios than their non-varsity peers. Keshavarz et al., (2017), found that right hand 2D:4D average of elite Greco-Roman wrestlers was 0.93, while their left hand 2D:4D average was 0.93; right hand 2D:4D average of non-elite Greco-Roman wrestlers was 0,97, while their left hand 2D:4D average was 0,98 and right hand 2D:4D average of control group was 0,98, while their left hand 2D:4D average was 0,99. When elite wrestlers and non-elite wrestlers and control group were compared separately, statistically significant difference was found between 2D:4D averages of both hands (p=0.0001). Based on these results, it can be said that there are differences between 2D:4D averages of groups doing sports and those not doing sports. However, significant difference was found only in right hand averages in our study. Giffin et al., (2012), made assessment by using the averages of both hands and reported significant difference in their study. Keshavarz et al., (2017), found significant difference in 2D:4D averages of both hands. It is thought that the difference between digit ratios can be resulting from endocrine system or genetic factors. When the literature is reviewed, statements and results can be found which report that different results about 2D:4D ratios can be resulting from different reasons. For example, Manning and Hill (2009), found that low 2D:4D ratio associated with prenatal testosterone (high prenatal testosterone) was associated with high sportive performance. For this reason, it is not possible to argue exactly for sure that 2D:4D averages are a determining factor in athletes. In addition, according to the results of all studies, it is not possible to talk about a standard average in 2D:4D ratios. This difference can be associated with the fact that the studies were conducted in different countries. Manning et al., (2000), found significant differences in 2D:4D lengths between populations of different ethnicities.

When right hand 2D:4D and left hand 2D:4D average values were compared in the sedentary group, no statistically significant difference was found, while significant difference was found in athletes. Statistically significant difference was found between right and left hand 2D:4D ratios in elite male swimmers in Acar and Eler (2018)'s study and in male taekwondo athletes in Kim [23]'s study ( $p < 0.05$ ). In the present study and in Kim (2016)'s study, left hand 2D:4D ratios are lower when compared with right hand 2D:4D ratios. According to these results, the difference between both hand 2D:4D averages of athletes can be associated with digit ratios being a determiner of sportive performance; however, according to these results, it is not possible to say which hand's lower 2D:4D averages can be predicted as a determiner of performance. This difference may be associated with ethnic characteristics.

In athlete group statistically significant difference was found between 2D:4D averages of both hands with all physical fitness parameters. Hill et al., (2012), ( $n=41$ ) found no significant relation between maximal oxygen uptake and right or left 2D:4D. Acar and Eler (2018), found negative correlation between right and left hand 2D:4D and both dominant and non-dominant hand grip strength of elite men swimmers. Eler and Eler (2018), also found negative correlation between right and left hand 2D:4D and both dominant and non-dominant hand grip strength of men elite handball players. In their study, Fink et al., (2006), found significant difference between 2D:4D ratio and hand grip strength in men ( $n=140$ ). Manning and Hill (2009), found that 2D:4D ratio of the right and left hand was negatively related to sprinting speed over 20 m, 30 m, 40 m and 50 m in a sample of teenage boys. Researchers generally found significant differences but Hill et al., (2012) found no significant relation in their study. According to these results, it cannot be said for sure that 2D:4D averages have an influence on physical fitness parameters.

As a conclusion, it can be said that health and performance related physical fitness states of male high school students doing sports are in general better than their peers who are not doing sport and that participation in sportive activities has positive influences on physical fitness levels of this age group. It can be said that finger ratios or lengths are associated with some motoric and functional dominance parameters; however, it is not possible to say from the results of the present study that they are determiners of physical performance and physical fitness. For future studies, comparing 2D:4D ratios and physical fitness measurements of individuals from different ethnicities with different procedures and different approaches can contribute to healthier results. It is thought that studies conducted on athletes and sedentary groups will be more effective in showing the distinctiveness of discussing sporting performance together with genetic, biochemical and psychological findings.

## References

- Acar, H., & Eler, N. (2018). The relationship of digit ratio (2D:4D) with cerebral lateralization and grip strength in elite swimmers. *Journal of education and training studies*, 6(4), 84-89. <https://doi.org/10.11114/jets.v6i4.3040>
- Acar, H., & Tutkun, E. (2017). Examination of some physical fitness characteristics in 13-14 year old footballers. *Acta Scientiae et Intellectus*, 3(5), 35-44.
- 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. <https://doi.org/10.1080/02640414.2010.510143>
- Çelenk, Ç. (2011). Farklı Branşlardaki Elit Sporcuların 2.ve 4. (2D:4D) Parmaklarının Oranının Sportif Performansa Etki Eden Bazı Biyokimyasal ve Endokrinolojik Parametrelerle İlişkisi. Gazi Üniversitesi, Sağlık Bilimleri Fakültesi, Doktora Tezi, Ankara,
- Çelik, A., Aksu, F., Tunar, M., Daşdan Ada, E. N., & Topaçoğlu, H. (2010). Master atletlerin fiziksel Performans düzeylerinin eldeki parmak oranlarıyla ilişkisi, *DEÜ Tıp Fakültesi Dergisi*, 24, 5-10.
- Eler, N., & Acar, H. (2018). The effects of the rope jump training program in physical education lessons on strength, speed and  $vo_2max$  in children. *Universal Journal of Educational Research*, 6(2), 340-345. <https://doi.org/10.13189/ujer.2018.060217>
- Eler, N., & Eler, S. (2018). 2D: 4D, Lateralization and Strength in Handball Players. *Journal of Education and Training Studies*, 6(5), 170-178. <https://doi.org/10.11114/jets.v6i5.3220>
- Fink, B., Thanzami, V., Seydel, H., & Manning, J. T. (2006). Digit ratio and hand-grip strength in German and Mizos men: cross-cultural evidence for an organizing effect of prenatal testosterone on strength. *Am. J. Hum. Biol.*, 18(6), 776-782. <https://doi.org/10.1002/ajhb.20549>
- Giffin, N. A., Kennedy, R. M., Jones, M. E., & Barber, C. A. (2012). Varsity athletes have lower 2D:4D ratios than other university students. *J. Sports Sci.*, 30, 135-138. <https://doi.org/10.1080/02640414.2011.630744>
- Gümüş, M., & Akalın, T. C. (2016). The Hand Preference of the National Sportsmen and Evaluation of The Grasp Forces, *International Journal of Academic Research*, 8(6), 45-50. <https://doi.org/10.7813/2075-4124.2016/8-6/A.5>
- Günay, M., Cigerci, A. E., & Aksen, P. (2011). The Evaluation Of Some Physical And Motor Features Of The Female

- And Male Students Aged 12–14 Who Participated In Sports Or Not. *Bulletin of the Transilvania University of Brasov Series VIII: Art. Sport*, 4(53).
- Hill, R., Simpson, B., Millet, G., Manning, J., & Kilduff, L. (2012). Right-left digit ratio (2D:4D) and maximal oxygen uptake. *J. Sports Sci.*, 30(2), 129-134. <https://doi.org/10.1080/02640414.2011.637947>
- Keshavarz, M., Bayati, M., Farzad, B., Dakhili, A., & Agha-Alinejad, H. (2017). The Second to Fourth Digit Ratio in Elite and Non-Elite Greco-Roman Wrestlers. *Journal of Human Kinetics*, 60, 145–151. <https://doi.org/10.1515/hukin-2017-0097>
- Kim, B. (2016). A Study of the Second Digit to Forth Digit Ratio targeting Taekwondo Athletes. *Indian Journal of Science And Technology*, 9(25). <https://doi.org/10.17485/ijst/2016/v9i25/97153>
- Longman, D., Stock, J. T., & Wells, J. C. (2011). Digit ratio (2D:4D) and rowing ergometer performance in males and females, *Am. J. Phys. Anthropol.*, 144(3), 337-341. <https://doi.org/10.1002/ajpa.21407>
- Lutchmaya, S., Baron-Cohen, S., Raggat, P., Knickmeyer, R., & Manning, J. T. (2004). 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Human Development*, 77, 23-28. <https://doi.org/10.1016/j.earlhumdev.2003.12.002>
- Manning, J. T., & Hill, M. R. (2009). Digit ratio (2D: 4D) and sprinting speed in boys. *American journal of human biology*, 21(2), 210-213. <https://doi.org/10.1002/ajhb.20855>
- Manning, J. T. (2002). The ratio of 2nd and 4th digit length and performance in skiing. *J. Sports Med. Phys. Fitness*, 6, 211–215.
- Manning, J. T., & Fink, B. (2008). Digit ratio (2D:4D), dominance, reproductive success, asymmetry, and sociosexuality in the BBC Internet Study. *American Journal of Human Biology*, 20(4), 451-461. <https://doi.org/10.1002/ajhb.20767>
- Manning, J. T., & Taylor. (2001). Second to fourth digit ratio and male ability in sport: implications for sexual selection in humans *Evol. Hum. Behav.*, 22, 61–69. [https://doi.org/10.1016/S1090-5138\(00\)00063-5](https://doi.org/10.1016/S1090-5138(00)00063-5)
- Manning, J. T., Barley, L., Walton, J., Lewis-Jones, D. I., Trivers, R. L., Singh, D. et al. (2000). The 2nd:4th digit ratio, sexual dimorphism, population differences, and reproductive success: Evidence for sexually antagonistic genes? *Evolution and Human Behavior*, 21, 163–183. [https://doi.org/10.1016/S1090-5138\(00\)00029-5](https://doi.org/10.1016/S1090-5138(00)00029-5)
- Manning, J. T., Scutt, D., Wilson, J., & Lewis-Jones, D. I. (1998). The Ration of 2. To 4. Digit Length: a prediditor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Human Repord*, 13(11), 3000-3004. <https://doi.org/10.1093/humrep/13.11.3000>
- Özer, K. (2001). Fiziksel uygunluk. Nobel Yayın Dağıtım, Ankara,
- Paul, S. N., Kato, B. S., Hunkin, J. L., Vivekanandan, S., & Spector, T. D. (2006). The big finger: the second to fourth digit ratio is a predictor of sporting ability in women. *British Journal of Sports Medicine*, 40, 981-983.
- Simons, J., Beunen, G. P., Renson, R., Claessens, A. L M., Vanreusel, B., et al. (1990). Growth and fitness of Flemish girls: the Leuven Growth Study. Champaign, Il.: *Human Kinetics*. 173.
- Vaeyens, R., Lenoir, M., Williams, A. M., & Philippaerts, R. M. (2008). Talent identification and development programmes in sport. *Sports medicine*, 38(9), 703-714. <https://doi.org/10.2165/00007256-200838090-00001>

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