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Original

VARIATION OF DIGIT RATIO (2D:4D) IN ATHLETES AND DIFFERENCES WITH SPORTS GROUPS

VARIACIÓN DEL INDICE DIGITAL (2D:4D) EN ATLETAS Y DIFERENCIAS CON GRUPOS DE DEPORTES

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RESUMEN

El objetivo de este estudio fue determinar la variación y asociación del índice digital (2D: 4D) de los atletas sobre la mano derecha (2D: 4DD), mano izquierda (2D: 4DI), el valor medio (2D: 4DM) y la asimetría (2D: 4DA) con diferentes disciplinas deportivas. 1178 atletas de 25 disciplinas deportivas y 29 países se agruparon en cuatro categorías de deportes: Resistencia (*n* = 267, 22,7%), Potencia (*n*= 354, 30,1%), Balón (*n*= 344, 29,2%) y Combate (*n*= 213, 18,0%). La medición directa de la longitud de los dedos 2D:4D de ambas manos se realizó utilizando calibradores digitales electrónicos de precisión. Las proporciones de dígitos se calcularon para ambas manos. Los principales resultados fueron: Entre los grupos con la muestra agrupada por sexos, utilizando el ANOVA bidireccional, se encontraron diferencias significativas entre el grupo Balón en comparación a los tres grupos para 2D:4DL y 2D:4DM. El grupo de deportes de Pelota fue dividido en Oposición *vs* Cooperación y se observó diferencias en 2D:4DI, con mejor promedio en oposición. Estos hallazgos sugieren que los deportes de pelota se diferencian de otros deportes en relación con 2D:4D; principalmente en 2D:4DL y 2D:4DM. La no diferencia en 2D:4D entre los grupos de Resistencia, Potencia y Combate. Estos resultados tienen varias implicaciones importantes en la detección y selección de talentos y ayudarán a tomar decisiones sobre los programas de formación.

Palabras clave: Índice Digital 2D:4D, Deportes de Rendimiento, Talentos Deportivos; Clasificación de Deportes.

ABSTRACT

The aim of this study was to determine the variation and association of digit ratios (2D:4D) of athletes on right hand (2D:4DR), left hand (2D:4DL), the mean value (2D:4DM) and the asymmetry (2D:4DA) with different sport disciplines. 1178 athletes from 25 sports disciplines and 29 countries were grouped into four sport categories: Endurance (*n*= 267, 22.7%), Power (*n*= 354, 30.1%), Ball (*n*= 344, 29.2%) and Combat (*n*= 213, 18.0%). Direct measurement of finger lengths of 2D and 4D fingers for both hands were performed using precision electronic digital calipers. Digit ratios were estimated to both hands. The main results were: Between groups with the pooled-sex sample, using the two-way ANOVA, significant differences were found among the Ball group in relation to the three groups for 2D:4DL and 2D:4DM. The Ball sports group was split into Opposition vs Cooperation and differences are made in 2D: 4DI, with better mean in opposition. These findings suggest that the Ball sports differ from other sports in relation to 2D:4D; mainly in 2D:4DL and 2D:4DM. The non-difference in 2D:4D between the Endurance, Power. These results have several implications important in the talents detection and selection and, will help to make decisions on training programs.

Keywords: Ratio 2nd:4th finger, Sports Performance, Sports Talent, Sports Classification.

INTRODUCTION

Specific knowledge of physiological and psychological capabilities is essential to understand the demands of different sports disciplines (Degens et al., 2019). No less important is to know the appendicular anthropometric traits, especially when identifying and classifying young athletes with the potential to be successful at the highest level of performance (Baker et al., 2013). The ratio between the finger lengths of the index finger (2D) to the ring finger (4D) is the digit ratio (2D:4D), it has been linked to sports achievements and high performance (Kilduff et al., 2011; Manning & Taylor, 2001).

In the last decades, evidence has accumulated that associates the ratio 2D:4D, physical abilities and psychological characteristics in the sport. Likewise, it was reported the mean (R+L/2; 2D:4DM) and asymmetry (R-L; 2D:4DA), with the prenatal influence of sex steroids (Lutchmaya et al., 2004). It's variation sexually dysmorphic has been widely studied for more than six decades (Phelps, 1952), finding variations in 2D and 4D length between the two sexes with a predominance of female until puberty (~ 13 years), reversing after in favor of male (Manning & Fink, 2018). However, the stability of the 2D:4D with the growth is still under study, since there are contradictory studies on the matter, although sexual dysmorphia (male <female) remains regardless of allometric growth (Manning & Fink, 2018).

Several theories have been proposed to explain lateralization, finally, all of them although in a different way, include the role of testosterone (T) on brain patterns in utero, thus, it can lastly be deduced that this hormone might masculinize both the physiology, anatomy, and behavior of an individual (Fink et al., 2004). A study, in 65 children it was evidenced the relationship of dominance with prenatal testosterone , measured in amniotic fluid, concluding that high levels of prenatal testosterone were strongly related to the left hemisphere dominance (Lust et al., 2011).

Anatomical patterns such as the 2D:4D are prenatally organized and strongly influenced by levels of androgenic steroid hormones (Lutchmaya et al., 2004). T is clearly linked with muscular performance (Kilduff et al., 2013), and therefore with athletic abilities (Cheung & Grossmann, 2018). Muscular performance plays a decisive role when reaching the objective in sports competition (Aikawa et al., 2020). Muscle strength, a basic physical ability regularly developed in athletes regardless of level and sporting experience, is related to 2D:4D in both women and men (Arazi & Eghbali, 2019). It has been observed a negative relationship between muscle power output (e.g., jump tests or reaction times) and 2D:4D (Hsu et al., 2018; Tambe et al., 2017). In addition, several studies have shown the correlation between cardiorespiratory fitness markers and 2D:4D (Hill et al., 2012; Holzapfel et al., 2016). Though the physiological capacities and abilities: strength, power, aerobic capacity, and others, are related to 2D:4D; is need more studies in this line of research.

These abilities help to classify sports to know which physical and psychological abilities connect most strongly with the relationship between 2D:4D and athletic prowess. Various approaches have been proposed for a sports classification (Frick et al., 2017; Matveev, 1991) e.g., one divides the sports into open- and closed-skill, which is based on the ability to suppress inappropriate actions both planned and in progress (Frick et al., 2017; Wang et al., 2013). Other is based on the muscle strength component which has a broad sports number groups, from those sports with static muscle contractions to those with higher dynamic contractions (Mitchell, Haskell et al., 2005). Matveev's (1991) classification is based on the demanding physical capacities and abilities for each sport, dividing them into four groups: Endurance, Power, Ball, and Combat. Many authors have evaluated the association between 2D:4D with different physiological, physical, and psychological abilities, within specific sport modality (for example, Frick et al., 2017; Hsu et al., 2015; de la Cruz-Sánchez et al., 2015; Longman et al., 2011) .

Therefore, the aim of the present study was determining the variation and difference between 2D:4D with different sport disciplines classified in four sports groups according to the Matveev's classification. We could not assure certainty what association was like, although it was assumed that the sports demanding greater physical and psychological skills would have the most marked and negative differences in digit ratios 2D:4D.

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MATERIAL AND METHODS

This cross-sectional study was approved by the Bioethics Committee of the University of Caldas (CBCS-020-15. Act 015-15). Additionally, based on the Declaration of Helsinki (AMM, 2013) and Resolution 8430 of the *Ministerio de Salud de Colombia*, participants signed informed consent, and for minors informed consent from parents or representatives of their sports delegation.

Sample

A non-probability sample selected for convenience obtained 1178 athletes (67.2% males), 1073 (91.1%) Colombians and 105 (8.9%) participants from 29 countries and five continents (Africa 5.7%, Asia 9.5%, Europe 36.2%, Latin America 37.1%, North America 11.4%). The M_{age}= 23, ±9.5 years [*min*=13 - *max*=73]. Data were obtained during different competition periods in Colombia (Medellín, Cali, Palmira, and Bogotá). The sample comprised 25 sports disciplines which were sorted into four groups (Matveev, 1991): *Endurance* (Athletics long distances 52.1%, Cycling route 30.7%, Swimming long distances 4.1%, Skating races 1.9%, Triathlon 11.2%). *Power* (Athletics sprint 69.8%, Cycling track 7.3%, Swimming sprint 5.1%, Skating 4.2% Weightlifting 11.0%, Finswimming 2.5%). *Ball* (Badminton 6.1%, Basketball 23.8%, Baseball 1.2%, Soccer 7.6%, Soccer Hall 7.3%, Rugby 8.1%, Softball 4.1%, Squash1.5%, Tennis 5.2%, Table Tennis 3.5%, Volleyball 31.7%). *Combat* (Boxing 10.3%, Fencing 24.9%, Hapkido 18.8%, Judo 9.4%, Karate-do 8.9%, Wrestling 18.8%, Taekwondo 8.9%). The Ball Sports were subdivided into Opposition Sports: badminton, tennis, squash, table tennis, and Volleyball. Cooperation Sports: basketball, baseball, soccer, futsal, rugby.

Inclusion and exclusion criteria

Were included those with: (a) sport age of <5 years (b) having competed, at least nationally according to their competition standard. As 2D:4D is a stable characteristic, ex-athletes of international level attending the mentioned events were also evaluated. (c) Athletes with malformations, amputations, or traumatic injuries were excluded, as an appropriated measurement of the fingers is reduced.

Sociodemographic variables

Trough an *ad-hoc* questionnaire, the following were recorded: date of birth, sports age, the dominance of the hand, country or state it represents, sport and modality, scholarship (number of years approved) and the highest level reached. Stature and body mass were acquired by self-report, and BMI was calculated from the collected data. For all groups studied, right-hand dominance was prevalent above 90%.

Finger measurements

The length of the index and ring fingers of each hand was measured directly from the palms of the hands with Vernier-Sata® electronic digital micrometer calipers (model: SATA 91511) with an accuracy of 0.01 mm, following the technique described by Manning (1998). This technique was used since most of the data was collected directly at the competition or training sites. 2D:4D were estimated by dividing the length of the index finger by the length of the ring finger of each hand. The mean (2D:4DM) between hands was calculated by adding the 2D:4DR plus 2D:4DL and dividing by 2. The asymmetry (2D:4DA) between hands was calculated by subtracting the 2D:4DL from the 2D:4DR. Two repeated measurements were obtained on each athlete by trained professionals. Intra and inter-rater reliability were calculated against a criterion rater (Level III ISAK), finding small systematic errors <1.0% intra-rater and <1.5% inter-rater. We follow the same procedure made by Ramos et al. (2021).

Statistic analysis

The data treatment was carried out in three phases: coding, debug, and filtering of the data through a Microsoft Excel 2020 sheet (Redmond, WA, USA). The entire statistical study was performed using the SPSS statistical package version 24 (IBM Inc., Chicago USA). (1) An exploratory inferential analysis of the data to detect outliers, and measures of central tendency and dispersion were obtained. The Kolmogorov-Smirnov test to determine the distribution and the Levene´s test to evaluate homoscedasticity were used with $p > .05$. A Brown Forsythe test was conducted in case the homoscedasticity criterion was not met. (2) A statistical significance was established at $p < 0.05$.

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The effect size was estimated with eta squared (*ηp2*) considering low .01 values, between .02 and .06 medium, and > .06 high. Pearson's correlations were performed to explore relationships between anthropometric variables and digit ratios. (3) Means compared analysis One-way ANOVA was used to analyze differences in anthropometric variables by sex separately, using sports groups as a factor. A student t-test (two-tailed) was used when were needed comparing the means of two groups (e.g., between sex). A two-way ANOVA [4 (sport group) x 2 (sex)] was used for multiple comparisons of finger variables. A post hoc Fisher's LSD test was performed to find the main differences and standard errors (SE) between sports groups by sex group and vice versa.

RESULTS

Descriptive statistics

There were 1,178 participants in the data set, 386 women (32.8%), and 792 men (67.2%). Regards to the sports groups, there were 267 participating in Endurance sports: 34% women and 66% men; while 354 participated in Power sports: 22% women and 78% men, 344 did so in Ball sports: 28% women and 72% men, and finally 213 participated in Combat sports: 21% women and 79% men.

The total sample (M_{age}= 23.0, ±9.6) the oldest sports group was Endurance (M_{age}= 26.8, ±10.4), while the youngest were Power and Combat (M_{age}= 20.9, ±9.1; M_{age}= 20.7, ±7.9, respectively). The descriptive data of age and anthropometric variables are reported for each sex in *Table 1*. Women and men presented differences in anthropometric variables across the 4 groups; the main findings were as follows, women: height [$F(3, 382)= 11.06$, $p< .001$], body mass [$F(3, 382)= 17.79$, $p < .001$], and BMI [$F(3, 382)= 11.65$, $p< .001$], in men were: height [$F(3, 788)= 49.19$, $p<$ 001], body mass [$F(3, 788)= 55{,}73$, $p< .001$], and BMI, [$F(3{,}788)= 16{,}25$, $p< .001$]. As expected, the differences among sports groups in anthropometric variables are the product of specific characteristics of each sport modality (Leone et al., 2002).

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Table 1. Descriptive data M (±) of the Anthropometric variables according to Sports Groups

	Endurance(267)	Power(354)	Ball(344)	Combat(213)
Women(n)	(90)	(155)	(97)	(44)
Age[years]	23.9(8.8)	19.5(8.6)	24.6(9.9)	19.6(4.7)
Body height[cm]	161.9(7.6)	167.0(8.6)	168.3(9.7)	163.3(7.6)
Body mass[kg]	53.7(7.9)	60.5(11.5)	65.3(13.1)	59.2(8.0)
Body-mass index[Kg/m2]	20.5(2.3)	21.6(3.1)	22.9(3.4)	22.1(2.1)
Men(n)	(177)	(199)	(247)	(169)
Age[years]	28.4(11.0)	21.9(9.5)	23.3(8.8)	20.9(8.6)
Body height[cm]	171.2(7.4)	176.7(9.0)	180.0(10.6)	170.7(9.8)
Body mass[kg]	63.0(7.4)	72.1(13.3)	75.7(13.0)	63.9(12.1)
Body-mass index[Kg/m2]	21.5(2.1)	23.0(3.4)	23.2(3.3)	21.8(2.9)

Entire Sample

When the means (±) of the whole sample considered together was evaluated, it was observed that the length of 2DR= 71.58(±5.69), while in the 4DR= 75.43(5.87), in the left hand, the 2DL= 72.38(5.69), and 4DL= 75.10(6.05). Regarding the digit ratios, the following values were found: 2D:4DR= 0.950(0.04), 2D:4DL= 0.964(0.04), 2D:4DM= 0.957(0.03) and 2D:4DA= -0.015(0.04).

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Ball sport split: Opposition and Cooperation

Ball Sport was split between Opposition and Cooperation (see table 2). The 2D:4D l (left) showed differences between opposition and cooperation Ball sport, better in sport Opposition.

Table 2. Digit Lengths Ball Sport split between Opposition and Cooperation

	Opposition M(SD)	Cooperation M(SD)	*t*	*d*
2D:4DR	0.949(0.04)	0.954(0.03)	-1.13	-0.12
2D:4DL	0.967(0.03)	0.976(0.04)	-2.02*	-0.22
2D:4DM	0.958(0.03)	0.965(0.03)	-1.95	-0.21
2D:4DA	-0.018(0.04)	-0.022(0.04)	0.82	0.09

Note: R: Right, L: Left, A: Asymmetry is the difference= R-L.
**p> .04*

Differences among sports groups pooled

Table 3 showed the differences among the groups derived by two-factor ANOVA's with independent variables group (4 levels) and sex (2 levels), and dependent variables 2D or 4D or 2D:4D, which determined significant differences among sports groups in some variables of digit ratios. Post hoc Fisher's LSD analysis allowed found that the Ball group was significantly different from the other three groups (i.e., Endurance, Power and Combat). These last three did not establish significant differences among them.

Sports groups differences in 2D:4D by sex

Table 4 showed the differences between group sport segmented by sex. Post hoc Fisher's LSD test revealed that in men, the 2D:4DL of the three sports groups Endurance, Power and Combat differed significantly from the Ball group: [Ball-Endurance, *p*= < .001; Ball-Power, *p*= .006; Ball−Combat, *p*= .003]. Similarly, in 2D:4DM, the Endurance and Power groups differed significantly from the Ball group: [Ball-Endurance, *p*= .012; Ball-Power, *p*= .027]; while, Combat showed only a trend [Ball-Combat, *p*= .076]. Likewise, 2D:4DA was significantly different between the Combat and Ball groups: [Ball-Combat, *p*= .015], and a trend was observed between Endurance and Ball [Ball-Endurance= − 0.008, *SE*= 0.004, *p*= .056]. No significant differences among groups were observed in 2D:4DR in the men subsample.

On the contrary, the women subsample exhibited in 2D:4DR significant differences between the groups of Ball and Endurance [Ball-Endurance, *p*= .028], while Power and Combat showed a trend in this variable [Ball-Power, *p*= .095; Ball-Combat, *p*= .067]. In contrast, in 2D:4DL, the women of the Ball group differed from their pairs of Power and Combat: [Ball-Power, *p*= <.001; Ball-Combat, *p*= .002]. And there established a trend regards to Endurance: [Ball-Endurance, *p*= .090]. In 2D:4DM the three groups: Endurance, Power and Combat were significantly different with respect to Ball, [Ball-Endurance, *p*= 0.019; Ball-Power, *p*= .003; Ball-Combat, *p*= .003]. The 2D:4DA only showed a trend between Endurance and Power, *p* = .065.

Table 3. Digit lengths and ratios among sports groups with the pooled sample M(±)

	Endurance (*n*= 267)	**Power (*n*= 354)**	**Ball (*n*= 344)**	**Combat (*n*= 213)**	***F***	***p***	η_p^2
2D:4DR	0.947(0.03)	0.949(0.04)	0.953(0.04)	0.948(0.04)	2.24	.081	0.006
2D:4DL	0.962(0.03)	0.962(0.04)	0.972(0.04)	0.959(0.03)	8.25	<.001	0.021
2D:4DM	0.955(0.03)	0.956(0.03)	0.963(0.03)	0.954(0.03)	6.51	<.001	0.016
2D:4DA	-0.015(0.04)	-0.012(0.04)	-0.020(0.04)	-0.011(0.04)	2.15	.092	0.005

Note: R: Right, L: Left, A: Asymmetry is the difference= R-L

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Table 4. Digit ratios among sports groups segmented sample by sex.

	Endurance (267)	Power (354)	Ball (344)	Combat(213)	***F***	***p***	η_p^2
Women(n)	(90)	(155)	(97)	(44)			
2D:4DR	0.950(0.04)	0.954(0.04)	0.962(0.04)	0.950(0.03)	2.24	.081	0.006
2D:4DL	0.970(0.03)	0.964(0.03)	0.979(0.04)	0.959(0.03)	8.25	<.001**	0.036
2D:4DM	0.960(0.03)	0.959(0.03)	0.971(0.03)	0.954(0.02)	6.50	<.001**	0.031
2D:4DA	-0.020(0.05)	-0.009(0.04)	-0.017(0.05)	-0.009(0.04)	2.39	0.243	0.011
Men(n)	(177)	(199)	(247)	(169)			
2D:4DR	0.945(0.03)	0.946(0.04)	0.949(0.04)	0.948(0.04)	0.52	.665	0.002
2D:4DL	0.959(0.03)	0.960(0.04)	0.970(0.04)	0.959(0.04)	4.29	<.005**	0.016
2D:4DM	0.952(0.03)	0.953(0.03)	0.959(0.03)	0.954(0.03)	2.46	.044*	0.009
2D:4DA	-0.013(0.04)	-0.015(0.04)	-0.021(0.04)	-0.011(0.04)	2.65	0.063	0.010

*Note: M(±)., 2D:4D: ratio of the second-to-fourth finger length; R=Right, L=Left, M=Mean; A=Asymmetry. η_p^2= effect size eta squared. **=p<0.01; *=p<0.05*

DISCUSSION

We examined whether at least one of the 2D and 4D measurement could differentiate sports groups. We found that: (1) In the total sample, eliminating the effect of sex, the Ball group in relation to the other three groups (Endurance, Power, and Combat) presented the highest values in all 2D and 4D length. (2) The Endurance, Power, and Combat groups, which mostly include individual-based sports, did not found significant differences among them, suggesting that additional to endurance running, other physiological and/or psychological abilities associate with 2D:4DL and 2D:4DM. (3) By sex, it was indicated that in the women, the lowest values in 2D:4DR, 2D:4DL, 2D:4DM, and the highest in 2D:4DA were found in the Combat group. While, the men, 2D:4DR, 2D:4DL, 2D:4DM presented the lowest values in the Endurance group, again, only 2D:4DL and 2D:4DM achieved significant differences in the Ball group. (4) It was confirmed that sexual dimorphism is also observed in athletes for all measurement.

Sex differences in 2D:4D within sports groups

The Power and Ball groups obtained significant differences in 2D:4DR by sex. In the Combat group, not significant differences were found, which warrants further follow-up. Meanwhile, within the Endurance group, men obtained lower values than women, but not significantly in all variables, except in 2D:4DA. Our results were accord with Manning et al. (2007), when observing in men endurance athletes the significantly lower than women values (2D:4DL-M). Other studies have negatively related 2D:4D to VO_{2max} in men, mainly on the right hand, since the highest VO_{2max} values have been perceived in Endurance sports, with a sexually dimorphic expression in favor of men (Lombardo & Otieno, 2020; Sandbakk et al., 2018).

Differences in 2D:4D among sports groups pooled

When it was compared 2D:4D digit ratios among the four sports groups, independently of the sex effect, there were significant differences among the four groups in 2D:4DL-M. Also, it was found that the Power group yielded the lowest value in 2D:4DA and the highest in 2D:4DR-L-M. Studies with sample of tennis athletes have reported higher 2D:4D in Ball sports than those found in the present study (Hsu et al., 2015). The fact that most of the sports modalities of Ball group are team-based sports involve varying degrees of development in psychological, social skills (Arias et al., 2016); physical, and physiological abilities, such as aerobic power, anaerobic power, muscular power (Degens et al., 2019). In contrast, Endurance, Power, and Combat groups which are frequently individual sports, their athletes have other physiological, for example, greater muscular strength and anaerobic energy participation (Longman et al., 2011); and psychological skills, for example, sensation- and/or thrill-seeking behaviors, motivation or concentration (Kociuba et al., 2017; Olmedilla et al., 2018).

When comparing different sports branches, many studies to date have only focused on 2D:4DR and 2D:4DL (Kociuba et al., 2017; Lombardo et al., 2018; Tambe et al., 2017), and very few have examined 2D:4DM and 2D:4DA. The Ball group showed significant differences with the other three groups in 2D:4DM, which must be analyzed in context with the result in the 2D:4DL, whose value was significantly higher in the Ball group. Similarly, this led to the 2D:4DA to have a difference among the Ball group with the Endurance and Combat groups. The fact that the Ball group behaves differently with respect to the other three groups could be explained for characteristics of the team-based sports must develop cooperative and prosocial behavior (Koziel et al., 2016), and this trait is related to certain hormone levels. There is a strong link that relates low T levels to the less-developed social cognitive traits (Crespi, 2016).

Two probable explanations could be suggested in the 2D:4D within the Ball sports compared to other sports disciplines. The first and least likely to arise is that the Ball sports might somehow modify the 2D:4D throughout age, if it is compared that the Endurance, Power, and Combat. Some studies have linked the 2D:4D changes in school-age children, higher on the left hand than the right one (Williams et al., 2003). However, Manning & Fink (2018), in a recent work, observed in children and adults (≈n> 89,000) that 2D:4D is not dependent on age.

The second is that somehow a mechanism not totally understood so far. The prenatal hormonal profile related to androgens and estrogens have effects on specific physical and psychological capacities in ball sports, such as muscle coordination, which is dependent on neuromuscular development (e.g., agility) and/or psychological traits such as cooperative and prosocial behavior typical of team sports (Pepping & Timmermans, 2012). Also, sports Ball have social skills or muscular coordination that are priority (Koziel et al., 2016; Ré, et al., 2016). However, this is in the realm of assumption and will require prospective studies to confirm these hypotheses. These differences between team-based *vs*. individual-based sports, e.g., athletes involved in the combat sports, have some psychological traits, such as "sensation seeking" and activities implying high physical risk (Koziel et al., 2016) and develop physical skills such as grasping or striking (Barley et al., 2019).

Sports groups differences in 2D:4D by sex

The post hoc analysis tests showed strong differences in 2D:4DL across the four sports groups in both sexes. For 2D:4DR has observed only in women a significant difference between the Ball and Endurance group. In women and men, the Combat and Power groups share physical abilities that would differentiate them from the Ball group. For example, muscle power, in both Combat sports (Hübner-Wozniak, et al., 2004) and Power sports (Longman et al., 2011) is largely decisive for victory. Very few studies have reported data comparing different sports in 2D:4D digit ratios in female athletes (Kociuba et al., 2017). This study found that the lowest values in 2D:4DR in women were found in the Combat and Endurance groups, while the highest was in the Ball group. It can be argued that women have other factors than endurance running that could be influenced by prenatal androgens or estrogens exposure., e.g., muscle strength (Shen et al., 2016), muscular force-velocity (Hull, et al., 2015) and cognitive abilities (Kempel et al., 2005). While in men, the Endurance and Ball groups showed the lowest and highest respectively, while Power and Combat, however, without significant differences. The relationship between running and 2D:4DR has been reported consistently across a broad range of studies (Hönekopp & Schuster, 2010; Koziel et al., 2016).

Several important limitations need to be considered. The variable of maximum sports achievement did not reach enough records in the self-report form and the missing data did not allow them to be included in the analysis thus that an association between the finger variables and different performance standards was not possible to obtain. The elite athletes could be analyzed in contrast with non-athletes. Also, new studies about of relationship psychological and motor abilities in experimental conditions could be showed results for talent identification in each sport. Likewise, to study other samples, for example referees and assistants may be novel (Aguirre-Loaiza et al., 2020). Finally, prospective studies are required that be able to control, a greater extent, the variables physiological and psychological implied in each sport modality to analyze their association with 2D:4D. These results contribute to the coach's analysis, equally about making decision talent detection and selection (Ayala-Zuluaga et al., 2015).

CONCLUSIONS

Consequently, our results indicate that the 2D:4D showed differences of the Ball Sport group, regards

Endurance, Power, Combat Sport groups. This difference persisted even within subsamples of sexes. At the same time, the split in Ball Sport Group (Opposition vs Cooperation) showed differences in 2D:4D left, favourable to Opposition Sport

Conflict of Interests

The authors declare that they have no conflict of interest with the content of this article.

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