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ORIGINAL

PHYSICAL CAPACITY HERITABILITY FROM PARENTS TO CHILDREN: COMPUTERISED DERMATOGLYPHICS

HEREDABILIDAD DE LAS POTENCIALIDADES FÍSICO-DEPORTIVAS DE PADRES A HIJOS: DERMATOGLIFIA COMPUTARIZADA

Gastélum-Cuadras, G.

PhD in Physical Activity and Health. Full Professor of the Doctorate Programme in Physical Culture Sciences, belonging to the national register of quality postgraduate programmes (Programa Nacional de Posgrados de Calidad, CONACyT). Head of the academic group Biopsychosocial factors, sport, physical activity and health (Factores Biopsicosociales, Deporte, Actividad Física y Salud). Autonomous University of Chihuahua. Member of the national researcher system (Sistema Nacional de Investigadores: SNI), level I (CONACyT). Academic Director of the International Human Motricity Network (IHMN) (Mexico) gastelum@uach.mx

Spanish-English translator: Rocío Domínguez Castells, rociodominguezcastells@gmail.com

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ABSTRACT

A multiple-case research design was chosen for this study. Four families, with two parents and two children each, and different levels of engagement in sport were analysed by means of sport digital dermatoglyphics. Aim: to confirm the genetic heritability of physical capacities from parents to children, the correlation

between dermatoglyphic patterns and sport performance, as well as the effectiveness of a computerised dermatoglyphic method. Results: genetic heritability of physical capacities from parents to children was confirmed by means of computerised dermatoglyphics. In some cases, each parent inherits his potentialities to a different child, in others, both children inherited them from their mother. Furthermore, children from families with strong engagement in sport and who were closer to high performance became more successful in sport. Validity and reliability of the instrument were confirmed, its accuracy, efficiency and effectiveness for scientific research being also proved.

KEYWORDS: epigenetics, sport, physical capacities, multiple-case study, computerised dermatoglyphics.

RESUMEN

El presente trabajo toma un diseño de investigación de estudio de casos múltiples. Se analizaron cuatro familias, conformadas por dos padres y dos hijos, con diferente nivel de involucramiento en el deporte. A través de la metodología de dermatoglifia dactilar deportiva. Objetivo: demostrar, la heredabilidad genética de las potencialidades físicas de padres a hijos, la correlación entre patrones dermatoglíficos y el rendimiento deportivo; así como la efectividad de un sistema dermatoglífico informatizado. Resultados: se demuestra relación hereditaria entre padres e hijos, a través del método dermatoglífico informatizado, en algunos casos cada padre hereda sus potencialidades a un hijo diferente, en otro es la madre la que otorga a ambos hijos. Además, las familias donde existe un fuerte involucramiento y más cercano al alto rendimiento, cuenta con hijos con más éxitos deportivos. Se confirma la validez y confiabilidad del instrumento, demostrando capacidad de precisión, eficiencia y eficacia para el estudio científico.

PALABRAS CLAVE: epigenética, deporte, potencialidades físicas, estudio de casos múltiples, dermatoglifia informatizada.

INTRODUCTION

In the last decades and at the beginning of this century, there has been animated discussion between two important research currents about phenomena related to human development. On one hand, geneticists believe that genetics is determining in an individual's life and that they are provided with the genetic foundations, which will express over time. On the other hand, another large group of scientists, the environmentalists, deem the environment as very important, for example: education, diet or social context in which the individual develops. They believe that full individual development is achieved thanks to an appropriate environment.

In spite of the above, nowadays the conclusion has been reached that neither of these positions separately adjusts to the existing human being realities. To the contrary, both are parts of one same whole, which contribute to better

understanding and research of phenomena related to people's life (Celestino, Leitão, & Pereira, 2019; García, 2009; Medina, 2019; Murialdo, 2019). In fact, a new concept has arisen: epigenetics, which, according to García, Ayala and Perdomo (2012, p. 60) "refers to heritable modifications of DNA and histones that do not entail changes in the nucleotide sequence but modify chromatin's structure and condensation, affecting gene expression and phenotype [own translation]", which are actually caused by environmental factors.

Sport has become especially relevant in the scientific study of human everyday activities, since it requires a series of physical, psychological and social capacities and skills in order to achieve physical performance. Thus, both aforementioned currents are involved with the aim to better explain phenomena that occur in human activities by means of methods, tools and technology.

In this regard, it cannot be denied that the use of science and technology (Ariza, Fernández-Jiménez, Muñoz-Calle, Sierra, & Mora, 2019; Pérez et al., 2019) in favour of sport performance and health has gained prevalence, to such extent that it may determine athletes' success or failure. The study of genetics is a very interesting aspect in the sports field, since it determines the physical capacities, but not forgetting that other factors, such as psychological or environmental (diet or training) ones are also of paramount importance for sport success. Therefore, the information provided by dermatoglyphics on individual biology is essential for sport specialisation, since phenotypic epigenetic markers, like dermatoglyphics, can reveal potential for high-performance sport at early ages. This can be useful to start a sport training process supported by science (Aljoe-Fernández, García-Fernández, & Gastélum-Cuadras, 2020; Gastélum-Cuadras, Valenzuela-Jurado, López-Alonzo, Chávez-Erives, & Fernández-Aljoe, 2020; Leiva, Melo & Gil, 2011; Medellín, 2018).

During the last few years, several authors have sustained a scientific debate in the sport sciences field about heritability of fingerprint patterns. Dermatoglyphics analysis revealed that there exist general laws as regards how such characteristics are inherited, showing that boys and girls present the same papillary patterns (arches, loops or whorls) as their parents. In fact, the heritability of dermatoglyphic characteristics allows them to be used, among other purposes, to determine paternity (Yarovenko, 2015). Moreover, according to sports dermatoglyphics, not only fingerprint patterns are hereditary, but also the physical capacities associated to those patterns.

Sports dermatoglyphics, a very widely used scientific methodology nowadays (de Jesus et al., 2019; Juárez-Toledo, et al., 2018; Monroy, Jiménez, Buitrago & Gutiérrez, 2019; Montenegro & Petro, 2019; Rodríguez et al., 2017 & 2019; Rodríguez, Montenegro & Petro, 2019; Sánchez & Rodríguez, 2017), refers to the study of fingerprints and their relationship with an individual's innate physical capacities. In this study, and avoiding any controversy, we will refer to the following physical capacities (Guío, 2011): absolute strength, speed, coordination, power, agility, hypertrophy, endurance and potential for high performance.

According to Abramova, Nikitina and Ozolín (1994), Del Vecchio and Goncalves (2011) and the majority of the aforementioned authors, the most common fingerprint patterns are: arch, loop and whorl (Figure 1). The arch (A) is a pattern with no core or deltas, and it is related to strength and power. The loop (L) is composed of three areas: base, core and delta, and it represents speed. There is a variation called radial loop, which experts directly associate with high performance, as its prevalence is high among elite athletes. The whorl (W) is a closed design with a central core and two deltas on the sides, and it is related to coordination and endurance. Lastly, one variation of the whorl is the S design, which contains two deltas on the sides but, unlike the previous one, it presents two cores creating an S-shape. This is a less common pattern, but it is also associated with coordination and endurance (Figure 1).

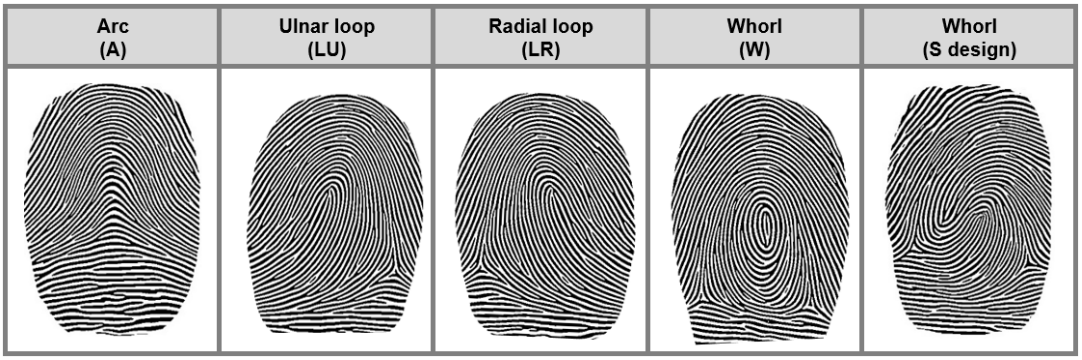

Figure 1. Common dermatoglyphic patterns in the human being.
Source: own elaboration.

The study of fingerprints as a genetic marker, as well as their relationship with morpho-functional and movement types of international-level athletes has gained special interest. The presence of arch, loop or whorl patterns was observed to vary across sport modalities. Thus, cyclic sports based on speed or strength with little coordination demands were associated with more simple fingerprint patterns (arches and loops), composed of a smaller number of ridges. By contrast, more complex fingerprints with a larger number of ridges are typical of sports with high coordination demands (Aljoe-Fernández et al., 2020; Leiva, Melo & Gil, 2011).

Nodari-Júnior, Heberle, Ferreira-Emygdio and Irany (2014) conducted a study with the purpose to correlate the traditional digital dermatoglyphics method with a computerised system. The computerised method was observed to be able to quantify the number of ridges more accurately and efficiently, proving to be reproducible and reliable. It was concluded that it is an effective method to capture, recognise, digitise and analyse fingerprint patters.

Aljoe-Fernández et al. (2020) provided a clear overview of the current situation of the use of technology in this field in Latin America. They published a systematic review where, out of 13 manuscripts selected, only three (Alberti et al., 2018; Hernández et al., 2013; Juárez-Toledo et al., 2018) reported to have used technology in their research. The other ten papers, including but not limited to Abad-Colil et al. (2015), Rodríguez et al. (2017, 2019) and Sánchez and Rodríguez (2017), reported to have applied the traditional methodology

proposed by Cummins and Midlo (1961). It consisted in collecting fingerprints using ink and paper or looking through a magnifying glass, and then observing the digital dermatoglyphics and counting ridges.

AIMS

The aims of the present study were to prove, on one hand, physical capacity heritability from parents to children and the correlation between dermatoglyphic patterns and sport performance and, on the other hand, the effectiveness of the computerised dermatoglyphics system.

MATERIAL AND METHODS

Dermatoglyphic protocol and instruments for data collection

1. **Coputerised dermatoglyphic reader**

Digital dermatoglyphics was applied to measure and analyse innate physical capacities. The protocol proposed by Cummins and Midlo (1961) was followed, which consists in collecting fingerprints from the ten fingers. Traditionally, this was done using ink and paper or looking through a magnifying glass, while a computerised dermatoglyphic reader was used in the present study (Nodari et al., 2008; Nodari & Heberle, 2014). This device is composed of a bearing optical scanner that collects and interprets the image and builds a binary code, providing real (greyscale) and binary (black and white) images. After all fingerprint images are collected, the Lector Dermatoglífico® (dermatoglyphic reader) user selects the images one by one, joins the points contained in the loops and whorls, in each case, and traces Garlton's Line. This is an imaginary line that starts in the centre of the core and ends in the centre of the delta or deltas (Rodríguez, Montenegro & Petro, 2017). The software is then programmed to draw the intersection of the Line with the fingerprint ridges, providing the number of ridges in each finger and the design pattern of each fingerprint. Lastly, the software conducts qualitative image identification, quantifies the number of ridges and generates an Excel sheet with all the data, as well as an individual dermatoglyphics report (Appendix 1), which contains qualitative and quantitative data regarding physical capacities, including an easy-to-interpret graph (Nodari et al., 2008).

2. **Computer survey on general details**

This instrument was designed *ad-hoc* in Google Forms. It contained the participants' demographic details and information related to family sport history, among others. Every family completed the survey online.

Research design

Four cases were addressed in this manuscript, each of them referring to one family where one child practises sport activity at a certain level and with certain aims, sometimes involving parents and siblings as well. Based on this, a

multiple-case research design was chosen, each case containing analysis sub-units. This means that families were considered as cases and family members as research sub-units (Jiménez & Comet, 2016; Yin, 2018). In accordance with the proposed research design, basic descriptive statistics and qualitative data analysis were applied to the fingerprint patterns observed in each case and individual. The study inclusion criteria were: families with parents (mother and father) and biological children, with at least two children involved (regardless of gender), and at least two members (one adult and one child) involved in physical activity.

Case description

- ✓ **Case 1.- Family with background in recreation and health sports:** composed of four members. A 7-year-old girl and a female 13-year-old adolescent practise recreation and health swimming. Their parents, aged 44, used to play basketball, and the mother also used to play volleyball and swim. In fact, she was selected in primary and secondary school in volleyball and basketball. Sport is important to this family.

- ✓ **Case 2.- Family with background in sports during basic education:** composed of four members. A male 13-year-old adolescent plays football at school. The father, aged 51, used to play when he was young and was selected in football and basketball until college. The 51-year-old mother and the 16-year-old sister reported to never have liked sports or physical education. The mother explained that she suffered from asthma and her family did not allow her to practise sport or physical education, and the daughter argued that she never felt motivated, actually the opposite, due to the bad practices of her physical education teachers. Sport is relatively important to this family. In this case, two more family members were added: a brother of the father, aged 44, and a brother of the mother, aged 43.

- ✓ **Case 3.- Family with background in University performance sport:** composed of four members. A 6-year-old boy does not practise sport yet and a male 17-year-old adolescent plays football and has been selected since primary school until college (level at the moment of the study) with noteworthy results. The 41-year-old father and the 39-year-old mother used to be successful student athletes, he in volleyball (national pre-selection) and she in table tennis, obtaining silver and bronze medals, respectively, at national University championships. Sport is extremely important to this family.

- ✓ **Case 4.- Family with background in international elite sport:** composed of four members. Two 9 and 14-year-old boys have achieved international success in racquetball, repeatedly finishing in the first or second places. The father, aged 42, used to play racquetball and practise judo. Nowadays, he is an internationally successful racquetball trainer. The mother, aged 39, used to play racquetball and swim successfully. Sport is extremely important to this family.

Ethical considerations

The present study resulted from the research project *Physical capacity heritability from parents to children: computerised dermatoglyphics* (Heredabilidad de las potencialidades físico-deportivas de padres a hijos: dermatoglifia computarizada), with registration page 08102019-149, as stated at the Secretary for Research and Postgraduate of the Faculty of Physical Culture Sciences, Autonomous University of Chihuahua, Chihuahua, Mexico. It was conducted fully complying with professional rules and ethics, following the Declaration of Helsinki and always letting participants' interest (and confidentiality) prevail over the researcher's scientific interest. Besides, it was considered to entail no risks, as only demographic details and fingerprints were collected after written informed consent was provided by both parents.

RESULTS

Case 1.- Family with background in recreation and health sports

We will start describing the results of Case 1. In general, it is a family with very similar characteristics, reflected on most physical capacities. Endurance was different between the mother and the other family members, as she presented 30% while the rest presented 70% or above. This revealed that the daughters inherited endurance from their father. The younger daughter did not present any radial loop, which correlates with potential for high performance. However, she showed the highest coordination and agility values, as she was the only one presenting whorls (Table 1, Figure 2).

Table 1. *Fingerprint pattern prevalence, total number of ridges and dermatoglyphic formula for family 1.*

Case 1	A	RL	UL	W	SW	D10	SQTL	DF TYPE
Mother	0	1	9	0	0	10	42	**10L**
Older daughter	0	1	9	0	0	10	116	**10L**
Younger daughter	0	0	8	2	0	12	119	**L>W**
Father	1	1	8	0	0	9	134	**L>A**

Source: own elaboration.

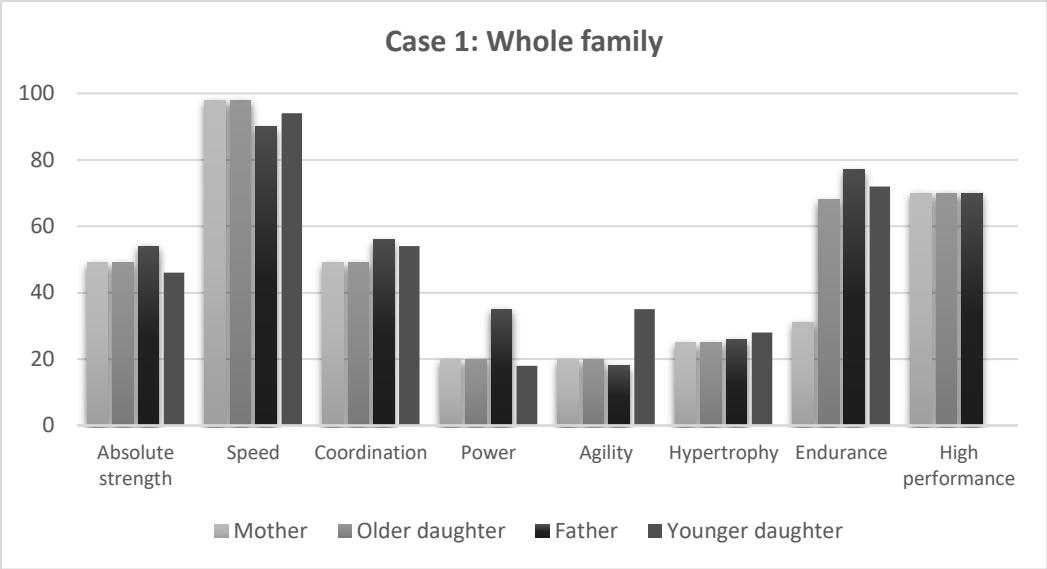

Figure 2. *Scores achieved by family 1 for innate physical capacities.* **Source:** own elaboration.

In particular, a clear heritability relationship was observed between the mother and her older daughter, both showing the same dermatoglyphic formula (10L). The only difference, as mentioned above, was noted in endurance (Table 1, Figure 3).

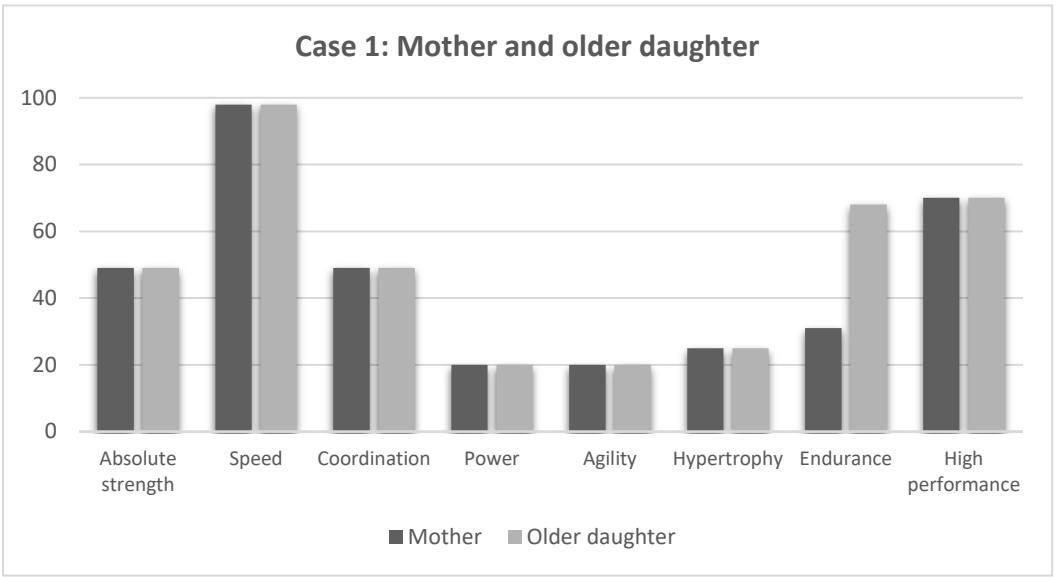

Figure 3. *Scores achieved by the mother and the older daughter of family 1 for innate physical capacities.* **Source:** own elaboration.

Case 2.- Family with background in sports during basic education

As regards Case 2, homogeneity of physical capacities can be noted in this family, especially between the father and his younger son, who presented very similar dermatoglyphic profiles. They actually obtained the same scores for the first six capacities and they presented the same type of dermatoglyphic formula (TDF). Likewise, the mother and her older daughter showed similar physical capacity patterns (Table 2, Figure 4).

Table 2. *Fingerprint pattern prevalence, total number of ridges and dermatoglyphic formula for family 2.*

Case 2	A	RL	UL	W	SW	D10	SQTL	DF TYPE
Mother	5	0	5	0	0	5	19	**A=L**
Mother's brother	5	0	5	0	0	5	42	**A=L**
Older daughter	3	0	7	0	0	8	42	**L>A**
Younger son	0	2	8	0	0	10	89	**10L**
Father	0	0	10	0	0	10	137	**10L**
Father's brother	1	1	8	0	0	9	134	**L>A**

Source: own elaboration.

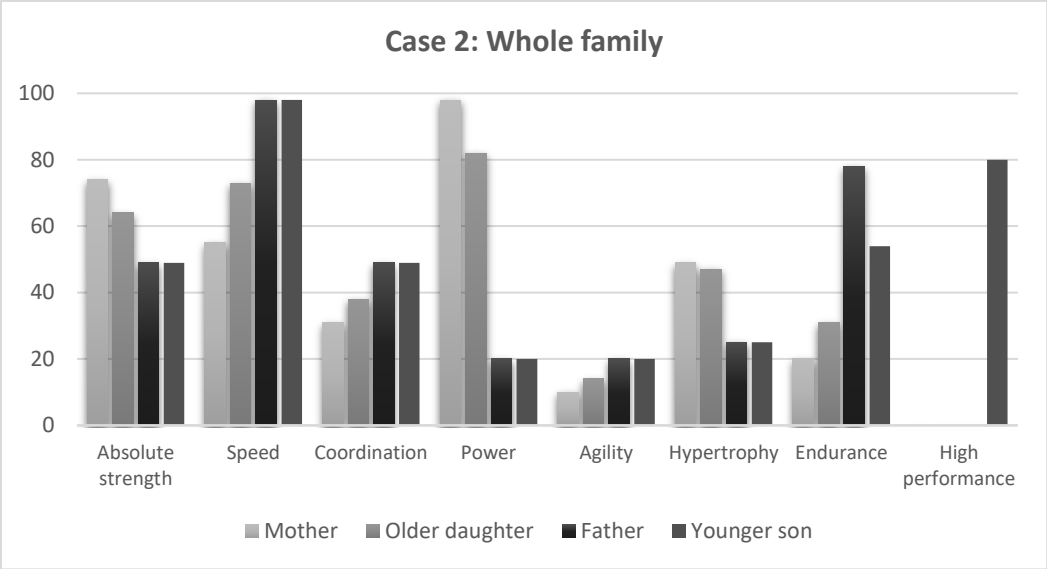

Figure 4. *Scores achieved by family 2 for innate physical capacities.*
Source: own elaboration.

Figure 5 shows how the father and his younger son scored exactly the same in the first six physical capacities, confirmed by the same dermatoglyphic formula (10L). Differences were only found in endurance, in which the father reached higher level. Besides, the son presented radial loop patterns on the fingerprints of both index fingers (Table 2), which indicates 80% of potential for high performance. Furthermore, speed and endurance were the best physical capacities in both of them. Lastly, the father's brother was observed to present very similar characteristics to father and son; in fact, he presented a radial loop like his nephew (Figure 5).

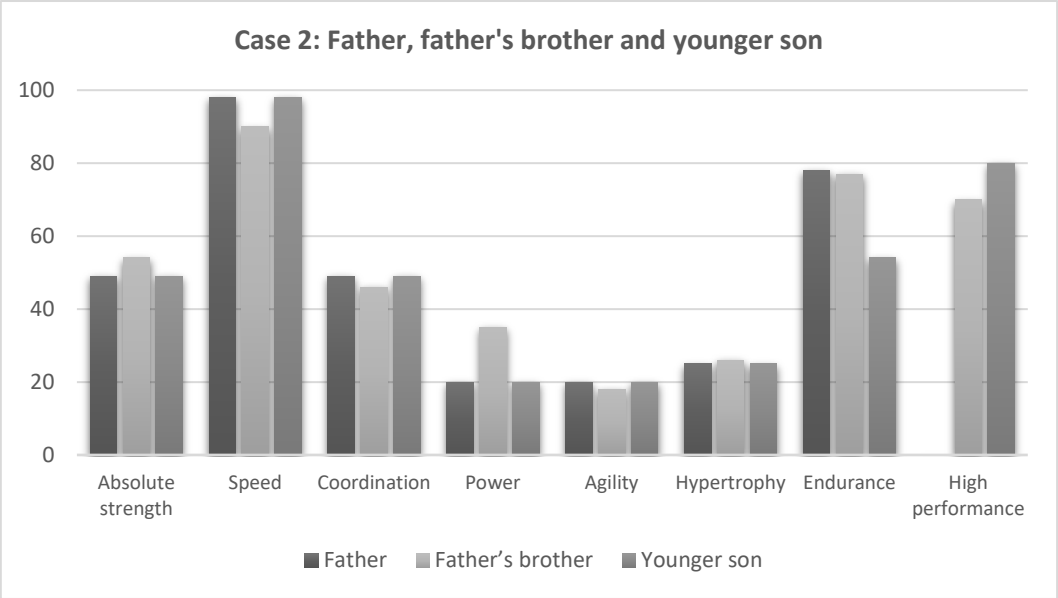

Figure 5. *Scores achieved by the father, the younger son and the father's brother of family 2 for innate physical capacities.* **Source:** own elaboration.

A similar situation occurred between the mother and her older daughter. They presented very alike physical capacity patterns, although slight differences were noted in strength, power, speed, endurance and coordination. The mother achieved higher levels in the first two, while the daughter did in the last three. The mother's best physical capacities were power and strength, while the daughter's were power and speed (Figure 6). The mother's brother showed very similar characteristics to mother and daughter; in fact, he presented the same dermatoglyphic formula (A=L) as the mother (his sister) and the same endurance level as his niece (Figure 6, Table 2).

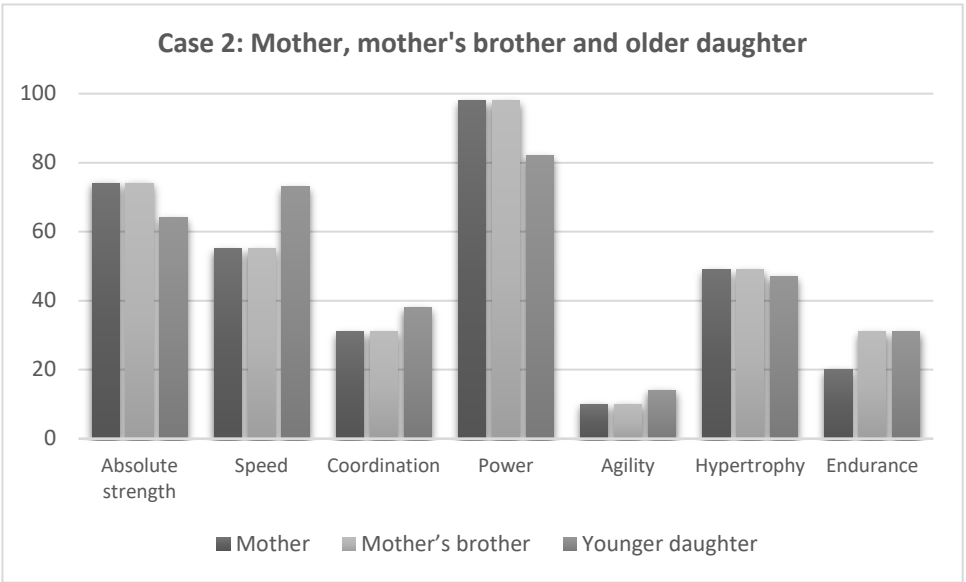

Figure 6. *Scores achieved by the mother, the mother's brother and the older daughter of family 2 for innate physical capacities.* **Source:** own elaboration.

Case 3.- Family with background in University performance sport

According to the results (Table 3, Figure 7), this family presented very similar profiles in general. It is noteworthy that the mother showed a strong relationship with her two sons, the three of them presenting the same dermatoglyphic formula (W>L), although it was similar to the father's (L>W).

Table 3. *Fingerprint pattern prevalence, total number of ridges and dermatoglyphic formula for family 3.*

Case 3	A	RL	UL	W	SW	D10	SQTL	DF TYPE
Mother	0	0	2	8	0	18	198	**W>L**
Older son	0	0	3	7	0	17	200	**W>L**
Younger son	0	0	2	8	0	18	190	**W>L**
Father	0	2	4	3	1	14	162	**L>W**

Source: own elaboration.

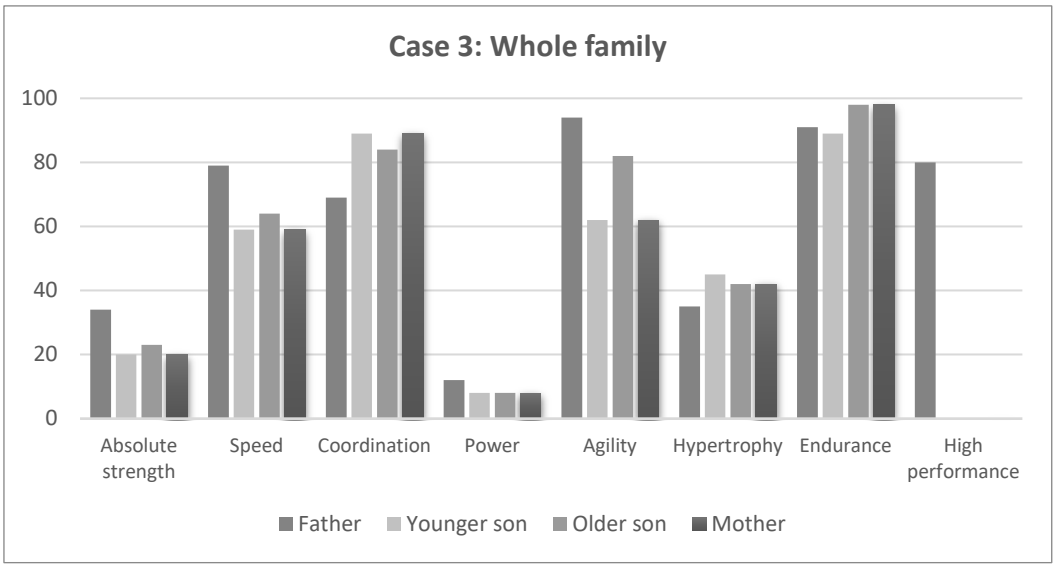

Figure 7. *Scores achieved by family 3 for innate physical capacities.*
Source: own elaboration.

As metioned above, the mother and her two sons showed very similar profiles (Figure 8); nevertheless, the older son presented higher speed and agility, which were related to his father's scores (Figure 7).

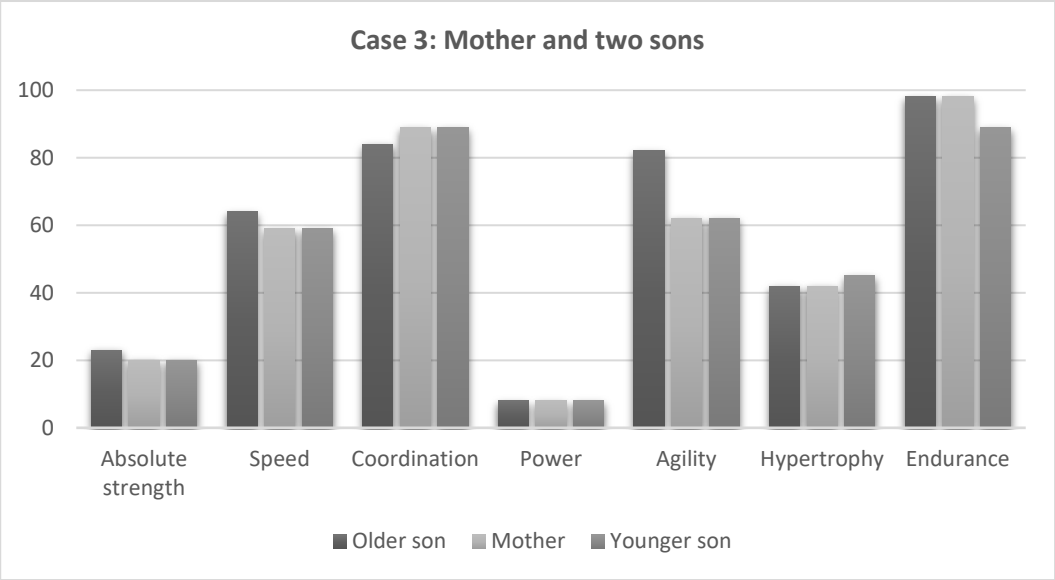

Figure 8. *Scores achieved by the mother and the two sons of family 3 for innate physical capacities.* **Source:** own elaboration.

Case 4.- Family with background in international elite sport

The results obtained for family 4 clearly revealed that, in general, the younger son inherited from his mother and the older son from his father (Figure 9). This can be observed in their dermatoglyphic formulas, the first presenting L>W and the latter W>L (Table 4).

Table 4. *Fingerprint pattern prevalence, total number of ridges and dermatoglyphic formula for family 4.*

Case 4	A	RL	UL	W	SW	D10	SQTL	DF TYPE
Mother	0	0	8	2	0	12	126	**L>W**
Younger son	0	0	8	2	0	12	104	**L>W**
Older son	0	0	3	7	0	16	152	**W>L**
Father	0	0	3	7	0	16	169	**W>L**

Source: own elaboration.

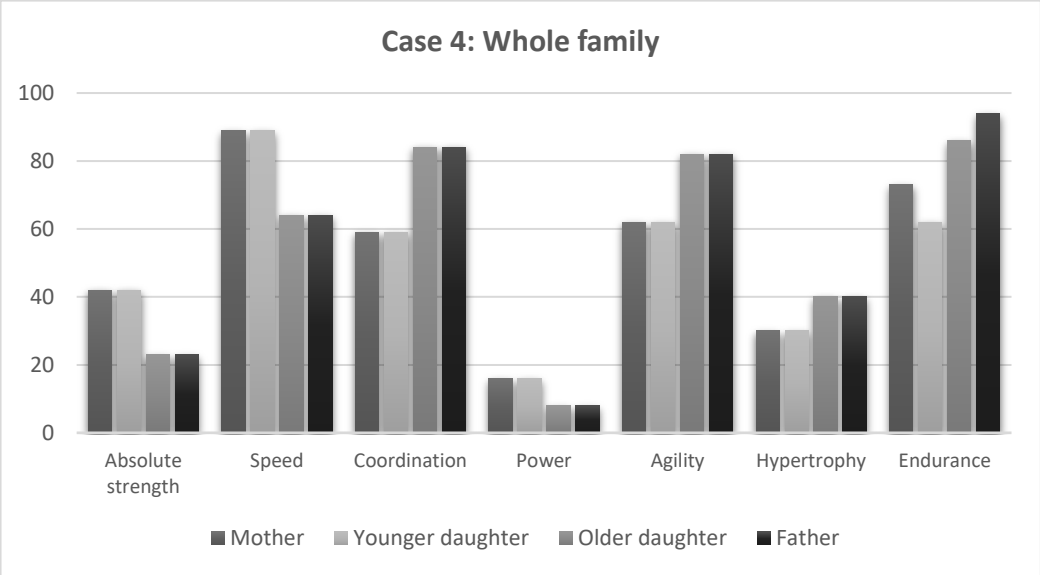

Figure 9. *Scores achieved by family 4 for innate physical capacities.*
Source: own elaboration.

According to Figure 10, which shows the results obtained for the father and his older son, they achieved the same scores in the first six physical capacities. Only a minimum difference was detected in endurance, in which the father scored higher.

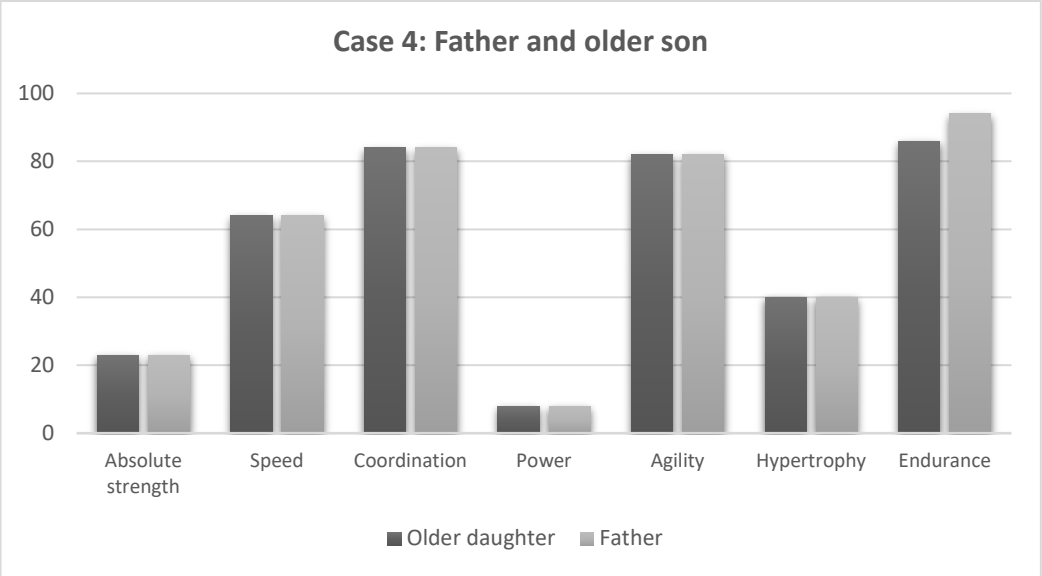

Figure 10. *Scores achieved by the father and the older son of family 4 for innate physical capacities.* **Source:** own elaboration.

The same occurred between the mother and her younger son, although with different percentages. Differences were only found in endurance, the mother scoring higher in this case (Figure 11).

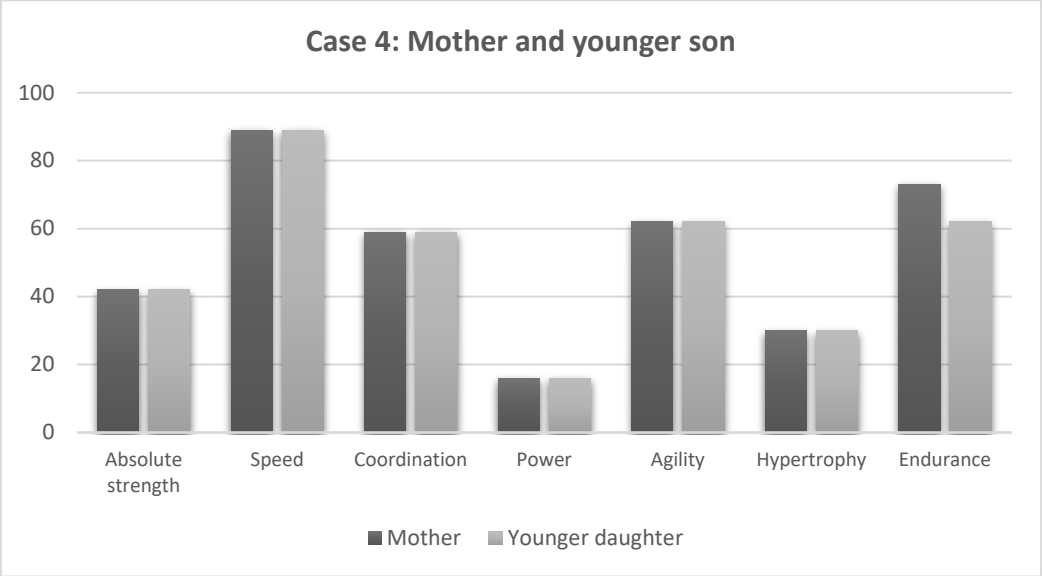

Figure 11. *Scores achieved by the mother and the younger son of family 4 for innate physical capacities.* **Source:** own elaboration.

DISCUSSION

The most relevant findings from all cases analysed will be presented below and subsequently discussed.

In the first family, a clear heritability relationship (same dermatoglyphic formula) was observed between the mother and her older daughter. The father only contributed to increase her resistance, as the mother did not present a high level of this capacity. The younger daughter did not show a clear heritability

relationship with her father or mother, although she was not very different either. Nonetheless, she presented special characteristics that should be confirmed with close relatives of both parents. For example, she did not present radial loops, in contrast to the rest of family members analysed. Furthermore, she showed whorl fingerprints, related to coordination and agility, which were not found in the rest of the family. The members of this family showed a dermatoglyphic profile associated with sports like middle-distance running and swimming, among others, since they presented high levels of speed and satisfactory levels of endurance.

In the second family, the genetic relationships were very clearly divided. On one hand, the older daughter inherited from her mother, which was confirmed by the mother's brother's characteristics. On the other hand, the younger son inherited his capacities (and dermatoglyphic formula) and loop fingerprint from his father; despite this pattern being recessive in the father, it was found in the father's brother. The older daughter presented greater resistance than her mother, which could be due to two reasons: it was inherited from her father or from her mother's family, since her mother's brother showed the same endurance level. Speed was doubtlessly received from her father. The male members of this family showed physical capacities related to long- and middle-distance running and swimming, among other sports, since they presented high levels of speed and high to very high endurance. The female members showed potential for athletics events such as throws or jumps, since they presented high strength and very high power levels. Nevertheless, up till now, none of them have made use of their potential.

In the third family, both sons clearly received their genetic characteristics from their mother; they showed the same formula and, of course, very similar physical capacities. However, the older son presented higher speed and agility, which was related to the scores obtained by his father. The parents of this family took advantage of their physical potential (speed, coordination, agility and endurance), since both practised sports at University (volleyball and table tennis) with good results. Besides, the older son plays football at a relatively high level and with high expectations for the future, due to his potential, the family experience and the support for sport provided by his parents.

In the last family, heritability was divided. In this case, the younger son inherited from his mother and the older son from his father, each pair showing the same dermatoglyphic formula. Furthermore, like the third family, all members showed capacities like speed, coordination, agility and endurance, the father and the older son achieving the best scores. This explains the good results achieved by the sons of this family in racquetball.

The evident heritability shown in all cases described in the present study is in keeping with Yarovenko (2015), who supported the existence of general laws of characteristic heritability that can be revealed by dermatoglyphics. He found that boys and girls presented the same papillary patterns (arches, loops or whorls) as their parents, as well as the physical capacities associated with those patterns (de Jesus et al., 2019; Juárez-Toledo, et al., 2018; Monroy, Jiménez, Buitrago & Gutiérrez, 2019; Montenegro & Petro, 2019; Rodríguez et

al., 2017, 2019; Rodríguez, Montenegro & Petro, 2019; Sánchez & Rodríguez, 2017).

It is worth mentioning that, in three out of the four families, there was at least one member with radial loop fingerprints, whose prevalence is higher among high-performance athletes. Nevertheless, it was actually not found in the family with good results in international-level sport, proving that it is not a requirement to achieve relevant sport goals.

The type of sport practised by parents and children (and those recommended by the author) were in accordance with Leiva, Melo and Gil (2011) and the authors cited above, who stated that cyclic, speed-based sports with little coordination demands are associated with more simple fingerprint patterns (arches and loops) composed of a smaller number of ridges. By contrast, more complex fingerprints (whorls) with a larger number of ridges are typical of sports with high coordination demands.

The expressions (high, very high, high potential, etc.) used to qualitatively assess the physical capacities described for each family were based on data from the dermatoglyphic profile provided by the authors of the computerised instrument used in this study (Nodari & Heberles, 2014).

Apart from the genetic potential of every family and individual, it was clearly shown that it is also necessary that adults encourage and support their children to engage in some sport or physical activity since, as it was mentioned above, the environment plays a very important role in the expression of innate genetic attributes. Thus, the members (parents and children) of those families who showed greater interest in sport were more successful in it (see Case description section).

Lastly, and despite more studies being needed, endurance and speed were the physical capacities most likely to be inherited from the less genetically-dominant parent. Moreover, this manuscript is considered to be the beginning of a research line on which there is limited literature, so these findings need to be confirmed by studies with larger samples in order to draw more robust conclusions.

CONCLUSIONS

Genetic heritability of physical capacities from parents to children was confirmed by means of computerised dermatoglyphics.

Furthermore, fingerprint formulas proved to be able to reveal the genetic influence of one parent's physical capacities on one or more children. Genetic potential, as well as parent support to their children's engagement in physical activity are essential in order to become successful in sports. The necessity that adults encourage and support their children to engage in some sport or physical activity was also highlighted since, as it was mentioned above, the environment plays a very important role in the expression of innate genetic attributes. Thus,

the members (parents and children) of those families who showed greater interest in sport were more successful in it. It seemed that endurance and speed were the physical capacities most likely to be inherited from the less genetically-dominant parent. Despite the high prevalence of radial loop fingerprint among high-performance athletes, it was not considered to be a requirement to achieve relevant sport results. Finally, further studies with different research designs and larger samples are needed to allow for generalisation of the findings of the present work.

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APPENDIX 1.- Examples of dermatoglyphic reports generated by the instrument for Family 3: father, mother and children.