Comparison of Whorl Types on the Palms of *Macaca mulatta* From the Taihang Mountains (Central China)

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Abstract: Background and objectives: The object of the present research is a study of the palmar whorls, Several unique features are characteristic for the palmar whorls of *Macaca mulatta* from the Taihang Mountains in central China. **Materials and Methods:** By direct observation striking dermatoglyphs were obtained from 65 specimens comprising 22 males and 43 females. **Results:** The whorls in the interdigital Ⅱ-Ⅳ areas on the palms of *Macaca mulatta* demonstrate a significant bilateral difference. On the left palm the major pattern is Wr constituting nearly 82.4% of the whorl patterns, while approximately 65.6% of the right palm is occupied by Wu. **Conclusions:** The results showed that the Wr on the left palm and the Wu on the right palm might be bilaterally symmetrical. A comparison between *Macaca mulatta* and *Macaca fuscata* showed that in both species the characteristics of the palmar whorls are very similar. Genetic factors play an important role, while environmental factors should not be neglected.

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1. Introduction

Dermatoglyphs are an essential morphological character in both human and non-human primates [1]. The complicated growth process of a dermatoglyph is affected by several elements such as the prenatal maternal environment, the level of testosterone during embryonic development and the palm shapes as well as by related genes[2,3,4]. During embryonic development the increasing influence of gene and environmental variations can cause abnormal developments in the dermatoglyphs [5,6].Dermatoglyph research is thus important for systematics and environmental control, life style, evolutionary grade and genetic pathology in different species. Bilateral asymmetry is a common phenomena in nature [2]. Currently only a few studies exist on the bilateral asymmetry of primate dermatoglyphs in China. Based on observations of rotational direction of palmar whorls in the interdigital II-IV area, this paper discusses their occurence and formation mechanism in order to provide basic information for a comparison of species and the evolution of primate dermatoglyphics.

2. Materials and Methods

Macaca mulatta inhabits the Taihang Mountains in northern Henan Province (N.Lat 34°54′～35°16′, E. Long 112°02′～112°52′) [7]. All the specimens of *Macaca mulatta* come from the Taihang Mountains. Details of gender are recorded in related documents. In this experiment we focus on 65 specimens consisting of 22 males and 43 females. According to the dental development and weights all the specimens are adult. The dermatoglyphs are obtained by photos or imprints. The images are analyzed by computer software Photoshop. The living *Macaca* are breeding in the rearing area of the School of Biological Science at Henan Normal University.

The object of the present research is a study of the palmar whorls. In general, the whorl has three patterns,pp. circular whorl, helicoidal whorl and deformed or degenerative whorl [8]. Circular whorls: the central line is composed of circles or concentric circles, sometimes with a certain deformation. Helicoid whorls have a central helicoidal zone with at least one spiral line rotating outside the center or near the center of the dermatoglyphs and the direction of the helicoidal whorls can be ulnar or radial. The deformed or degenerative whorls are mainly located in the interdigital III and IV area. These are rare, and do not have an apparent rotational direction and pattern center. Usually this type is difficult to confirm and it can be regarded as a transitional type or degenerative pattern.

The distribution of the whorls in the interdigital II-IV area on the palms is shown in Fig.1.

3. Results

The palmar whorls of *Macaca mulatta* appear mostly in the interdigital II-IV area, with a distribution frequency of 100%. Due to its rare occurence and uncertain rotational direction, Wv is classified as Wo. The distribution frequencies of Wu and Wo are shown in Table 1 and Table 2.

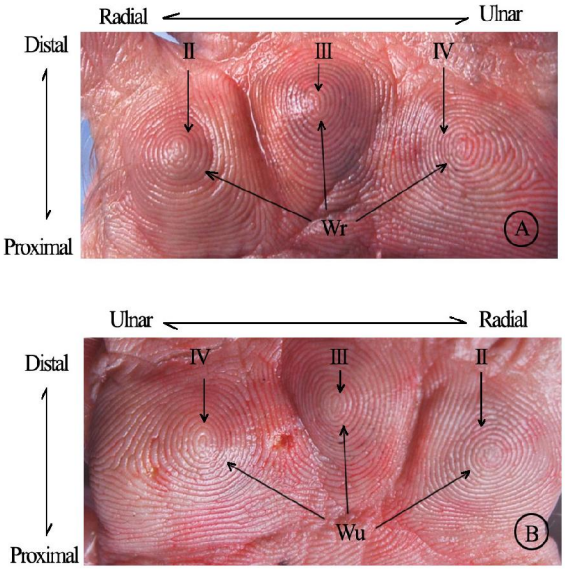

Figure1. Examples of most observable whorl types in the second, third, and fourth interdigital regions (Ⅱ, Ⅲ, and Ⅳ) between both hands in *Macaca mulatta*.

According to the rotational direction of the whorl an apparent bilateral discrepancy exists in the palmar whorls. The results are as follows,pp. (1) On the left palms the radical-rotation whorl (Wr) appears with a frequency of 83.1%~87.7% in the interdigital II-IV area, while the ulnar-oriented whorls in the same area have a frequency of 0.0%~4.6%. (2) On the right palms the ulnar-oriented whorls occur with a frequency of 60.0%-72.3% in the II-IV interdigital area, while the radical-oriented whorl (Wr) has a frequency of 9.2%-13.8%. (3) The left palmar Wr rotates in an anticlockwise direction as Wu does on the right palms. In other words, the rotational direction is the same on both palms. Neglecting the circular- and, deformed or degenerative whorls, the anticlockwise whorl constitutes 91.93% of all helicoidal whorls when the right and left palms are considered together and it demonstrates that the whorl has an apparent asymmetry of direction in the interdigital II-IV area. The frequency of Wu is very low in the interdigital II-IV area. Wu is not found in the interdigital III area and occurs only once in the interdigital IV area. (4) Wo is less frequent, the right side being greater than the left side and the middle greater than the bilateral.

Table 1. Occurrence frequency of Wr, Wu and Wo in the interdigital Ⅱ-Ⅳ patterns on the palms

Areas	Sex	Left				Right				Total			
		Wr	Wu	Wo	total	Wr	Wu	Wo	total	Wr	Wu	Wo	total
Ⅱ	♂	22	0	0	22	4	16	2	22	26	16	2	44
	♀	32	3	8	43	5	31	7	43	37	34	15	86
	♂+♀	54	3	8	65	9	47	9	65	63	50	17	130
Ⅲ	♂	21	0	1	22	3	15	4	22	24	15	5	44
	♀	36	0	7	43	3	24	16	43	39	24	23	86
	♂+♀	57	0	8	65	6	39	20	65	63	39	28	130
Ⅳ	♂	20	1	1	22	3	15	4	22	23	16	5	44
	♀	37	0	6	43	4	27	12	43	41	27	18	86
	♂+♀	57	1	7	65	7	42	16	65	64	43	21	130

Table 2. Distribution frequency of Wr, Wu and Wo on the palms of the Taihang *Macaca mulatta*

		Wr	Wo	Wu
Ⅱ	Left	54(83.1%)	8(12.3%)	3(4.6%)
	Right	9(13.8%)	9(13.8%)	47(72.3%)
Ⅲ	Left	57(87.7%)	8(12.3%)	0(0.0%)
	Right	6(9.2%)	20(30.8%)	39(60.0%)
Ⅳ	Left	57(87.7%)	7(10.8%)	1(1.5%)
	Right	7(10.8%)	16(24.6%)	42(64.6%)
total	Left	168(82.4%)	32(15.7%)	4(1.9%)
	Right	22(11.3%)	45(23.1%)	128(65.6)

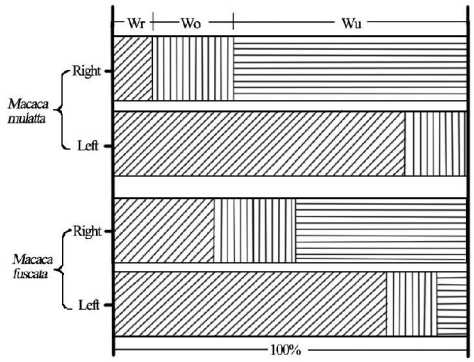

Figure 2. Comparisions of frequencies of Wr, Wo, and Wu in the second, third, and fourth interdigital patterns (Ⅱ, Ⅲ, and Ⅳ) between both hands

A comparison of the whorls in the interdigital area on the palms of Taihang *Macaca mulatta* and Japanese *Macaca mulatta* is shown in Fig.2. The result demonstrates that the frequency in the two populations of *Macaca mulatta* is similar to one another, with in decreasing frequency Wr-Wo-Wu on the left side and Wu- Wo-Wr on the right side.

4. Discussion

Dermatoglyphs are characteristic of primates. They are controlled by multiple genes and form between 13 and 19 weeks in the foetus. Dematoglyphs are inheritable, species-specific and stable. They are related with human physical strength, the degree of alertness and athletic abilities as well as some inherited diseases[8]. Previous studies mostly concentrated on the asymmetry of the numbers of dematoglyphic ridge on the palms and the influence of hormones during the early formative processes of the whorl [9]. Only a few studies have been devoted to the asymmetry of the palmar whorls.

Cauble and Mavalwa [10] studied dermatoglyphs on the palms of 70 *Macaca fascicularis*. Their results demonstrate that the rotational direction of the whorls has a striking discrepancy in interdigital III-IV patterns on the palms of *Macaca fascicularis* with the radial-oriented Wr on the left palm and the ulnar-oriented Wu on the right hand. Some studies of primates showed that the rotational direction of the patterns of hand are different from that of foot [11]. However they did not have a reasonable explanation for this phenomenon, and assumed that it is governed by the genetics of the genus *Macaca* or some other factors. Newell-Morris and Wienker [12]undertook detailed studies of the dematoglyphs on the palms of *Callicebus* and showed that the density of the pattern on the palms of three species of *Callicebus* is not related to sexual dimorphism and bilateral symmetry. They pointed out that their conclusion ran counter to research on other non-human primates. Additionally they mentioned that it is related with the dermatoglyphic differences in the different genera and species of primates. *Callicebus* may be different from Old World monkeys (such as *Macaca*) in the amount of sexual dimorphism and asymmetry [12]. Iwamoto[5,11]studied the whorls on the palms of 107 Japanese *Macaca*, and came to the conclusion that the apparent distinction in both palms in the interdigital II-IV pattern is based on the rotational direction of the whorls. His observation is similar to the statistical conclusion regarding the palmar whorls of Taihang *Macaca* reached in the present paper (Fig. 2). In his discussion he pointed out that the asymmetry of the interdigital whorl is negligable in the Japanese *Macaca* and other primates and that the origin of this asymmetry is difficult to understand [5,11]. The observations in the present paper are thus in accordance with the published record.

Although the reasons for the asymmetry of the palmar pattern in primates reproduction, size, types, position and the disparity of different taxa, and rare definite evidences could testify the asymmetry are controlled by genes and some environmental factors, many materials have proved the bilateral difference in palmar whorls in human and non-human primates and supplied with much evidence on physics, behavior and generation mechanism etc [13].

The formation of dermatoglyphs has been considered to be the result of genes and foetal environmental factors before the birth. Different human races have significantly different dermatoglyphic characteristics and these differences could help to unearth the history of organic evolution. There are both similarities and differences between the parental generation and filial generation, among siblings and in identical twins [14].

The rotational direction of the palmar whorls is inferred to be related to the gene regulation and control which has been proved experimentally. For instance, a double loop whorl on the palms of Taihang *Macaca mulatta* is located mainly on the proximal part of the hypothenar. Its rotational direction is radial with a double loop pattern (Zr) without bilateral asymmetry. In other words, Zr is displayed on the left palm as well as the right palm[15,16]. Arrieta et al. have studied the dermatoglypic characteristics of the palms of human twins and consider that the foetal factor is the main factor which effects the asymmetry line number in the interdigital a-b on the palms while the gene factor is minor [2]. This has been testified by other scientists.

One important result of this study is that Wr is displayed on the left palm and Wu on the right hand. Based on their anticlockwise rotational direction it is assumed that this phenomenon is bisymmetric and controlled by genes. Then due to some environmental factor Wo and Wu developed on the left palm and Wr on the right side, resulting in the bilateral asymmetry of the pattern.

The basis for this assumption is,pp. (1) The ridge counts and rotational direction of dermatoglyphs are controlled by genes and formed early on in the development of the embryo [13]. The embryonic environment and external environment may have some influence on the details of the dermatoglyphs, or even a substantial affect sometimes, but it is difficult to understand why both of the palms bear Wr when the formation of dermatoglyphs was completed, because the reverse restricted Wr to the left palm, with variation from Wr to Wu on the right hand. The exact mechanism responsible for this phenomenon is currently unknown. (2) In relevant publications it is

reported that the combinations of all types of whorls on the corresponding area on both palms have some internal relationship rather than a completely random one and indicate the degree of relationship between all types of whorl. The research of 90 kinds of combinations of lines left and right symmetry in the interdigital II-IV area on the palms of *Macaca mulatta* in Taihang showed that irregular combinations Wr/Wu 、Wr/Wo and Wo/Wu represent 89% of the total percentage, with the Wr/Wu type being particularly common (51.11%), while human Wo/Wo、Wr/Wr and Wu/Wu are less common (11% in total). This result demonstrates the irregular combination has a more intimate genetic affinity. Previous studies also support this assumption. For instance, Iwamoto[5] working on Japanese *Macaca mulatta* has shown that the main pattern in interdigital II-IV area is Wr with a percentage of 76.8% while the main pattern on the right palm is Wu with 48.0% of the total percentage. However this phenomena may not be applicable to humans. On the human finger Wr is greater than Wu on the left hand, while on the right hand it is quite the reverse [8]. (3) A high degree of asymmetry is characteristic of some interdigital areas, for instance, Wr appears in interdigital III and IV area on the palms of the Taihang *Macaca mulatta*, the frequency of Wu in interdigital III area and in interdigital IV being 0.0% and 1.5%, respectively. Moreover, according to Iwamoto in Japanese *Macaca mulatta* there is no Wu in the interdigital III and IV on the left palms [5]. It seems that this phenomenon is not purely accidental, at least in the genus *Macaca*. It is assumed that this characteristic is of taxonomic significance. (4) Sorenson-Jamison et al. [9] studied the influence of testosterone injection on the number of dermatoglyphs on the palms of *Macaca mulatta* before birth. They pointed out that the ridge number increased before the early period of gestation of humans but in monkeys the numbers decreased. For the two species the hormonal influence is striking but the effect is opposite, which would suggest a fundamental difference between humans and monkeys. During the life-span of a monkey, the palmar cactus retains a whorled pattern, while the palmar cactus in humans degenerates into a looped pattern or loses the pattern altogether[17].

According to the comparisons of two Japanese monkey and the observations in the present paper the main whorls on the palms of *Macaca mulatta* can be divided into three types,pp. Wr, Wu and Wo. The relationship between the different types is a very interesting issue. The frequency of the whorl types on the palms indicates that the order on the left palm is Wr→Wo→Wu but Wu→Wo→Wr on the right side. The result shows an inverse relationship. However, based on the above assumption, the result could be explained. The rotational direction is anticlockwise W → Wo → clockwise W, decreasing in frequency from anticlockwise W → Wo → clockwise W (Fig. 2). Thus it would appear that Wo is possibly a kind of transitional type. The whorls on the left side are more striking, which indicates during ontogeny the organism responds more positively to sinistral control, or that the effect of all kinds of interference factors is relatively weak. The possible reason for this phenomenon is as follows, (1) Asymmetry is an objective reality in the primate and it is normal during development that the symmetrical organism developed a striking asymmetry on account of the influence of ontogenetical interference factors, which have been proved repeatedly [18,19,20]. (2) According to some research the chimpanzee has handedness, the left hand and the right hand differ in the active frequency and flexibility of utilization and all these activities are controlled by different hemispheres[21,22,23], thus causing the bilateral difference of dermatoglyphs. (3) The numbers of finger ridges on both human hands are unequal, in 80% of all humans the number of finger ridges on the left hand is higher than on the right hand [8]. The high number of dermatoglyphs means an increased tactile sense. The patterns on the palms of primates has apparent bilateral asymmetry. This is possibly related to a functional difference between human and non-human primates. Further research will be needed to discover the exact factors responsible for these differences.

The above represents some of the issues related to in the characteristics, taxonomy and asymmetry of the whorls on the palms of *Macaca mulatta*. Many questions remain unsolved, for instance, the relationship between the bilateral differences and the function of both hands, the distribution of the whorls in the different interdigital areas, and the sexual and taxonomic significance of the differences between the whorls. None of these problems can be solved in the short term.

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