

<https://doi.org/10.25143/socr.19.2020.1.014-024>

Identification of Papillary Patterns in Human Fingers and Toes on the Basis of General Characteristics

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Abstract

The article gives a brief overview of the types of papillary ridge patterns of the skin, their location on the digits of fingers and toes. In this study, the authors of the article aimed to determine whether the papillary ridge patterns of a person's fingers and toes on the hands and feet of the same side are identical in terms of general characteristics. The methods used were the printing ink imprints on dactyloscopic maps and Microsil® impressions, and the comparison of the obtained impressions.

Keywords: papillary ridge patterns of the skin, general features, fingers, toes, Microsil®, comparison.

Introduction

Individuality of the papillary ridge pattern of the skin is manifested in the fact that the papillary folds form very diverse and complex shapes. Individuality and relative stability of the structure of the skin without papillary ridge pattern is related to

the anatomical structure of the dermis (Lindmäe, 1976). Based on the shapes formed by papillary folds, it is possible to classify papillary ridge patterns in a definite way.

Depending on the presence and number of delta, all papillary ridge patterns are classified into three types: looped, whorl and arch patterns, which in turn are classified as simple, complex, false (center consists of the main element of one type and the primary details of element types that belong to another pattern), rare, anomalous and differently shaped, and groups (Anishchenko, 2013).

According to the literature, about 65 % of all papillary ridge patterns on human fingertips are looped, 30 % have whorls and about 5 % are arches (Toporkov, 2015). Papillary patterns are distinguished by general and special characteristics. The general characteristics are the type and category of papillary ridge pattern, the direction of the papillary ridges and location of the delta, the wrinkles and bends in the papillary ridge patterns on the palms, fingers, soles of the feet and toes, which form in the tracks left in the bending and wrinkling areas. The special characteristics are the peculiarities of wrinkles and bends, as well as the details of the papillary ridge patterns, their shape, size and position.

Human footprints occur as either footwear tracks or bare footprints. In this case, the prints left by bare human feet are analysed. The bare foot imprint is formed by the toes, the ball of the foot, middle section or the longitudinal arch of the ball of the foot and heel. In most cases, the big toe protrudes further than other toes, in some cases, the second toe is the longest. Like with fingers, the bare foot has a papillary ridge pattern that is individual and permanent in shape.

The shape and location of the flexor muscle, the size of the ball of the foot, its length, its maximum width, the minimum width of the arch of the ball of the foot, the width of the section of the ball of the foot can all be considered to be anatomical differences. Features that characterise the ball of the foot include the configuration of the toes, the size of the toes, their relative position to each other.

The papillary ridge pattern of the skin on the sole of a person's foot has special characteristics because the ball of the foot and the digits of the toes have a more complex structure than the rest of the sole. The area of the ball of the foot that is adjacent to the toes has a three-beam pattern, i.e. triangles, on which sometimes loop patterns are located with the head of the loop towards the heel.

I. A. Anishchenko has written that the papillary ridge pattern on both the fingers and the toes falls under three types, but the whorl pattern is less common on the toes than the loop pattern, and the loop pattern is less common than the arch pattern. For example, big toes usually have loop patterns and rarely whorl patterns (Anishchenko, 2013).

On the surfaces of the toe joints, complex papillary ridges form, which vary, similarly as on the finger joints, in terms of type and category. This usually includes the large toe; its papillary ridge forms in the imprint; the imprint of the other toes has a distinguishable upper border pattern of the toe, which usually resembles an arched furrow in shape. As on the palms and fingers, there are elements of the skin of the ball of the foot

and toes that fall into a special category (scars, warts, amputations, blisters, sponge-like growths, scar tissue, malformations).

Aim of the Study, Methods and Material

The authors of this article aimed to determine whether the papillary ridge patterns of human fingers and toes on the hand and foot pairs on the same side are identical in terms of general characteristics. The objects of the analysis are comparable finger- and toeprints: the big toe and the thumb on the same side, the index finger and the second toe, the middle finger and the third toe, the ring finger and the fourth toe and the little finger and the little toe.

Fingerprints were transferred on dactyloscopic cards using black ink. Toeprints were partially printed on the dacto-cards (dacto-cards for the deceased). Most impressions were obtained using Microsil®: white, brown, gray and black. The need to use Microsil® was due to the relatively poor quality of imprints obtained with ink. A postmortem record strip holder used to obtain the ink prints; however, that did not allow the necessary access to all the toes. As a result, some of the toe imprints were only partially transferred: the upper border was formed, but the center part and the lower border patterns were lost. Because the Microsil® is elastic, its use made it possible to include all five toes and, in part, the ball of the foot, to obtain an impression. In a later examination, the elasticity of the Microsil® allowed the impression to be bent when examining it with a magnifying glass, and to obtain more detailed information about the traces formed.

Despite various anomalous manifestations, the gray, white, brown and black Microsil® gave very good results when storing toe impressions, considering the anatomical structure of the toe and the position of the toes in relation to each other, their length, the gap between the toes.

Good results were obtained for imprints created with black Microsil®. When examining them with a magnifying glass and in incident light, the reflection due to the gloss of the surface had to be taken into account. The results were very good with brown and gray Microsil® and the use of white Microsil® yielded excellent results. In the case of white Microsil®, soot powder had to be applied later to tint the imprints. The soot powder gives good contrast to the papillary lines formed on the white Microsil®.

The use of Microsil® has well highlighted the bending line on the big toe, which appears in the footprints as intervertebral folds; traces of folds between the folds of other toes are rare and may be related to pathology. The figures in the appendix illustrates the results obtained with Microsil®, whereas figure 1 shows imprints of toes stored in black Microsil®, in which the position of the toes relative to each other is clearly visible – the toes are partially behind the previous toe.

Figure 2 shows white Microsil® tinted with soot powder, both digits of the toe are visible (there are usually three on the fingers), which are compressed relative to each

other. The size of the toes is well distinguished and the digits with nails have a distinct papillary ridge pattern.

Figure 3 depicts imprints of toes stored in gray Microsil[®], showing toe spacing, length and position in relation to each other very clearly.

In Figure 4 the imprint has been created using brown Microsil[®], which shows the length of toes and their location behind each other.

Thus, it can be stated that by using Microsil[®], it is possible to distinguish the shape of the folds of the toe flexor muscles, their location; to estimate the size of the ball of the foot – maximum width; to evaluate the size, configuration and location of the toes.

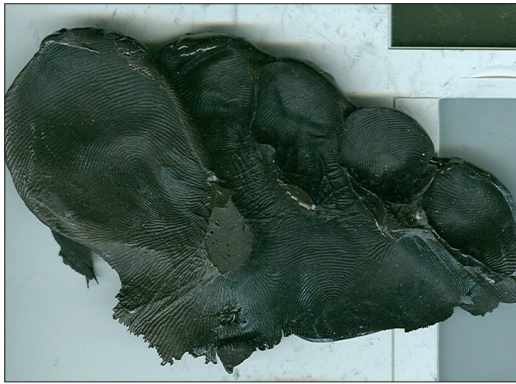


Figure 1. Toes of the right foot recorded with black Microsil[®]

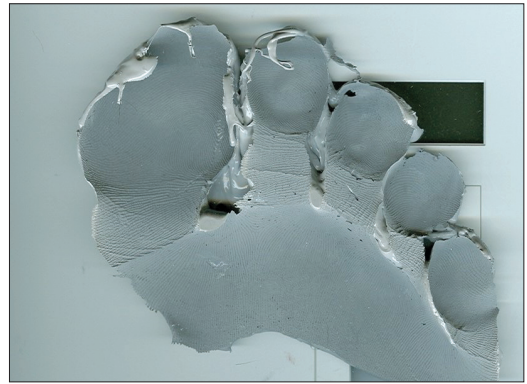


Figure 3. Toes of the right foot recorded with gray Microsil[®]



Figure 2. Toes of the right foot recorded with white Microsil[®], lightly tinted with soot powder



Figure 4. Toes of the right foot recorded with brown Microsil[®]

The cadets of the Police and Border Guard College of the Estonian Academy of Internal Affairs and the full-time undergraduate and postgraduate students of the Faculty of Law of the University of Tartu were included in the study. Participation in the study was voluntary and anonymous (N-woman, M-man were marked on the dacto-card; people could also sign their cards voluntarily).

The study involved 93 people, 55 of whom were men, 32 women and 6 people did not indicate their gender; thus they were treated as unidentified. Examination of the fingerprints and toes of the study participants revealed that 50 of the 55 male imprints were eligible for the statistical study; 5 men did not provide toe imprints; however, they did provide finger imprints. Of the 32 women, 23 were eligible for the statistical study; 9 women gave their fingerprints but did not provide toe prints. Data from 5 unidentified persons were eligible for statistical study, one had not provided their toe impressions. The current article does not present data on unidentified persons in a separate block, but presents the results of analysis carried on data provided by 50 men and 23 women.

Results of the Analysis

The study looked at men and women's data separately. The frequency of correspondence of papillary ridge patterns on the fingers and toes of men is shown in Table 1. Based on the results in the table, the following conclusions can be drawn:

- 1) **For the thumb and big toe**, the correspondence was 48 % on the right hand and foot, and 44 % on the left hand and foot. Of these, loop pattern was present in 38 % and 40 % of the cases; whorl pattern in 10 % and 4 % of the cases. Arch pattern, which is least common on the thumb and the big toe of the same arm and leg, was not identified;
- 2) **When comparing the index finger and the second toe** (right hand and foot), the match was 34 %, and on the left hand and 42 % on the foot. Of these, loop patterns occurred in 10 % and 22 % of the cases; whorl pattern in 14 % and 10 %, respectively. While no arch pattern was observed on the thumb and the big toe, the arch pattern was present in 10 % of the cases in both hands and feet on the index finger and second toe;
- 3) **When comparing the middle finger and the third toe** on both the right and left hand and foot, the correspondence ratio was 26 % and 24 %, respectively. The loop pattern occurred on the right hand and foot in 4 % of the cases, and on the left – 6 %, respectively; whorl pattern in 18 % and 16 %, and the least common arch pattern, in 4 % and 2 % of the cases;
- 4) **When comparing the ring finger and the fourth toe** on both the right and left hand and foot, the match was 30 % and 24 %, respectively. The loop pattern on the right hand-foot was 12 % and on the left – 14 %, respectively; whorl pattern 14 % and 8 % and arch pattern 4 % and 2 %;

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5) **The correspondence ratio of the little finger and the fifth toe** on both the right and left hand-foot was 20% and 14%, respectively. Of these matches, 8% were loop patterns on the little finger and fifth toe of the right hand, and 6% on the little finger and fifth toe of the left hand. Whorl pattern was not detected on little fingers and toes. Arch pattern occurred on the right hand-foot in 12% of the cases and on the left, correspondingly, in 8% of the cases.

Thus, it can be seen that no arch pattern was detected on the thumbs and big toes of both hands and feet. Also, no whorl pattern was detected when comparing the little fingers and toes of both hands and feet. In contrast, the incidence of the arch pattern of the middle finger and third toe and the ring finger and fourth toe was of equal value.

The correspondence ratio of papillary ridge patterns of women's fingers and toes has been represented in Table 2.

Table 1. Frequency of correspondence of papillary ridge patterns on the fingers and toes of men (number of persons and % of the sample)

Right hand and right foot	Correspondence ratio (%)		Left Hand and Left Foot	Correspondence Ratio (%)	
Thumb and big toe	24	48	Thumb and big toe	22	44
<i>loop pattern</i>	19	38	<i>loop pattern</i>	20	40
<i>whorl pattern</i>	5	10%	<i>whorl pattern</i>	2	4
<i>arch pattern</i>	0		<i>arch pattern</i>	0	
Index finger and the second toe	17	34	Index finger and the second toe	21	42
<i>loop pattern</i>	5	10	<i>loop pattern</i>	11	22
<i>whorl pattern</i>	7	14	<i>whorl pattern</i>	5	10
<i>arch pattern</i>	5	10	<i>arch pattern</i>	5	10
Middle finger and the third toe	13	26	Middle finger and the third toe	12	24
<i>loop pattern</i>	2	4	<i>loop pattern</i>	3	6
<i>whorl pattern</i>	9	18	<i>whorl pattern</i>	8	16
<i>arch pattern</i>	2	4	<i>arch pattern</i>	1	2
Index finger and the fourth toe	15	30	Index finger and the fourth toe	12	24
<i>loop pattern</i>	6	12	<i>loop pattern</i>	7	14
<i>whorl pattern</i>	7	14	<i>whorl pattern</i>	4	8
<i>arch pattern</i>	2	4	<i>arch pattern</i>	1	2
Little finger and the little toe	10	20	Little finger and the little toe	7	14
<i>loop pattern</i>	4	8	<i>loop pattern</i>	3	6
<i>whorl pattern</i>	0		<i>whorl pattern</i>	0	
<i>arch pattern</i>	6	12	<i>arch pattern</i>	4	8

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Table 2. Correspondence ratio of papillary ridge patterns of women's fingers and toes (number of persons and % in sample)

Right hand and right toe	Correspondence ratio (%)		Left hand and left foot	Correspondence ratio (%)	
	ratio	(%)		ratio	(%)
Thumb and big toe	11	48	Thumb and big toe	11	48
<i>loop pattern</i>	9	39	<i>loop pattern</i>	9	39
<i>whorl pattern</i>	1	4	<i>whorl pattern</i>	0	
<i>arch pattern</i>	1	4	<i>arch pattern</i>	2	9
Index finger and the second toe	12	52	Index finger and the second toe	10	43
<i>loop pattern</i>	7	30	<i>loop pattern</i>	4	17
<i>whorl pattern</i>	1	4	<i>whorl pattern</i>	2	9
<i>arch pattern</i>	4	17	<i>arch pattern</i>	4	17
Middle finger and the third toe	7	30	Middle finger and the third toe	13	56
<i>loop pattern</i>	2	9	<i>loop pattern</i>	4	17
<i>whorl pattern</i>	3	13	<i>whorl pattern</i>	5	22
<i>arch pattern</i>	2	9	<i>arch pattern</i>	4	17
Index finger and the fourth toe	6	26	Index finger and the fourth toe	7	30
<i>loop pattern</i>	2	9	<i>loop pattern</i>	4	17
<i>whorl pattern</i>	2	9	<i>whorl pattern</i>	2	9
<i>arch pattern</i>	2	9	<i>arch pattern</i>	1	4
Little finger and the little toe	6	26	Little finger and the little toe	6	26
<i>loop pattern</i>	3	13	<i>loop pattern</i>	4	17
<i>whorl pattern</i>	0		<i>whorl pattern</i>	0	
<i>arch pattern</i>	3	13	<i>arch pattern</i>	2	9

The following conclusions can be drawn from the study:

- 1) **For the thumb and big toe**, the correspondence ratio was 48% on the right hand and foot, and 48% on the left hand and foot. Of these, loop pattern was present in 39% and 39% of the cases; whorl pattern on the right foot – in 4% of the cases and none was found on the left hand-foot. Arch pattern occurred on the right hand and foot in 4% and on the left hand and foot in 9% of the cases;
- 2) **When comparing the index finger and the second toe** on the right hand and foot, the match was 52%, and on the left hand and foot – 43%. Of these, loop patterns occurred in 30% and 17% of the cases; whorl pattern – 4% and 9%, respectively. The arch pattern was detected in 17% of the cases in hand and foot pairs;
- 3) **When comparing the middle finger and the third toe** on both the right and left hand and foot, the correspondence ratio was 30% and 56%, respectively. The loop pattern occurred on the right hand and foot in 9% of the cases, and on the left – 17%, respectively; whorl pattern – 13% and 22%, yet the least common was arch pattern by 9% and 17%;

- 4) **When comparing the ring finger and the fourth toe** on both the right and left hand and foot, the match was 26 % and 30 %, respectively. The loop pattern on the right hand and foot was 9 % and on the left – 17 %; whorl pattern – 9 % and 9 %, and arch pattern – 9 % and 4 % in hand and foot pairs;
- 5) **The correspondence ratio of the little finger and the fifth toe** on both the right and left hand and foot was 26 % and 26 %. Of these, 13 % were loop patterns on the little finger and fifth toe of the right hand, and 17 % on the little finger and fifth toe of the left hand. Whorl pattern was not detected on little fingers and toes. Arch pattern was detected on 13 % of the right hand and foot and 9 % on the left hand and foot pairs.

Consequently, the correspondence between the thumb and big toe papillary ridge patterns on the right hand and foot and the left hand and foot were the same for the eleven women in the study, which equals 48 %. Out of these cases, loop patterns occurred in nine individuals, i.e. 39 % of the women in the study. The correspondence of the little finger and the little toe patterns was observed in six women.

Papillary patterns with whorls were not detected neither on the right or left hand and foot.

Comparing the data of men and women, it is interesting to note that women had more frequent correspondence in the patterns of papillary ridge patterns of fingers and toes than men. The largest differences were in the middle finger and third toe: while men had a 26 % match for the right hand and foot and 24 % for the left hand and foot, women had matches of 30 % and 56 %, respectively. There was also a big difference between men and women's index finger and second toe: while men had a 34 % match between the right hand and a foot, for women this figure was 52 %. There was also a significant difference between the little finger and little toe: while men had a correspondence of 20 % on the right hand and foot and 14 % on the left hand and foot, for women these values were 26 % and 26 %. The highest correspondence in the data for men and women was found for the thumb and big toe papillary ridge pattern matches – both for the right hand and foot (48 % for both men and women) and for the left hand and foot (44 % for men, 48 % for women).

Table 3 provides general data for all study participants.

The following conclusions can be drawn from the analysis:

- 1) **For the thumb and big toe**, the correspondence was 47.9 % on the right hand and foot, and 45.20 % on the left hand and foot. Of these, loop pattern was correspondingly present in 38.3 % and 39.72 % of the cases. Corresponding whorl pattern values were 8.2 % and 2.74 %. Arch pattern occurred on the right hand and foot in 1.4 % of the cases, and on the left hand and foot in 2.74 % of the cases;
- 2) **When comparing the index finger and the second toe** on the right hand and foot, the match was 39.7 %, and on the left hand and foot 42.4 %. Of these, loop patterns occurred in 16.43 % and 20.5 % of the cases; whorl pattern – 10.95 % and 19.58 %, respectively. Arch pattern was detected in 12.32 % of the cases on both sides;

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- 3) **When comparing the middle finger and the third toe** on both the right and left hand and foot, correspondence was 27.39% and 23.24%, respectively. The loop pattern occurred on the right hand and foot in 5.48% of the cases, and on the left – 9.58%; whorl patterns – 16.43% and 17.81%, and the least common was arch pattern by 5.48% and 6.85%;
- 4) **When comparing the ring finger and the fourth toe** on both the right and left hand and foot, the match was 28.76% and 26.02%, respectively. The loop pattern on the right hand and foot was 10.95% and on the left 15.06%; whorl patterns – 12.33% and 8.22% and arch patterns – 5.48% and 2.74%;
- 5) **The correspondence ratio of the little finger and the fifth toe** on both the right and left hand and foot was 21.91% and 17.80%. Of these, 9.58% were loop patterns on the little finger and fifth toe of the right hand. Whorl pattern was not detected on little fingers and toes. Arch pattern was detected on 12.33% of the right hand and foot and 8.22% on the left hand and foot.

Table 3. Correspondence frequency of papillary ridge patterns on fingers and toes of 73 subjects (number of subjects and % of the sample)

Right hand and right toe	Correspondence ratio (%)	Left hand and left foot	Correspondence ratio (%)
Thumb and big toe	35 47.9	Thumb and big toe	33 45.20
<i>loop pattern</i>	28 38.3	<i>loop pattern</i>	29 39.72
<i>whorl pattern</i>	6 8.2	<i>whorl pattern</i>	2 2.74
<i>arch pattern</i>	1 1.4	<i>arch pattern</i>	2 2.74
Index finger and the second toe	29 39.7	Index finger and the second toe	31 42.4
<i>loop pattern</i>	12 16.43	<i>loop pattern</i>	15 20.5
<i>whorl pattern</i>	8 10.95	<i>whorl pattern</i>	7 9.58
<i>arch pattern</i>	9 12.32	<i>arch pattern</i>	9 12.32
Middle finger and the third toe	20 27.39	Middle finger and the third toe	25 34.24
<i>loop pattern</i>	4 5.48	<i>loop pattern</i>	7 9.58
<i>whorl pattern</i>	12 16.43	<i>whorl pattern</i>	13 17.81
<i>arch pattern</i>	4 5.48	<i>arch pattern</i>	5 6.85
Index finger and the fourth toe	21 28.76	Index finger and the fourth toe	19 26.02
<i>loop pattern</i>	8 10.95	<i>loop pattern</i>	11 15.06
<i>whorl pattern</i>	9 12.33	<i>whorl pattern</i>	6 8.22
<i>arch pattern</i>	4 5.48	<i>arch pattern</i>	2 2.74
Little finger and the little toe	16 21.91	Little finger and the little toe	13 17.80
<i>loop pattern</i>	7 9.58	<i>loop pattern</i>	7 9.58
<i>whorl pattern</i>	0	<i>whorl pattern</i>	0
<i>arch pattern</i>	9 12.33	<i>arch pattern</i>	6 8.22

Therefore, it can be noted that the correspondence of papillary ridge patterns fingers and toes on the right and left hand varies from 2 to 5%. The fingers and toes with loop patterns have most correspondence, for hands and feet on both sides. The proportion of whorl pattern is lower for the left hand and foot, it should be also noted that whorl pattern was not detected on little fingers and toes on either side. The percentage of the arch pattern was relatively equal on all fingers and toes.

Summary and conclusions

For the 73 study participants, the correspondence between the papillary ridge patterns on the thumb and big toe on the right hand and foot and the left hand and foot is for more than 45% of the cases; loop patterns have been detected on hands and feet on both sides for less than 40%. Whorl pattern occurs on the right hand-foot approx. 3 times more than on the left, arch pattern on the left hand-foot approx. twice as much.

The correspondence of the papillary ridge patterns of the index finger and the second toe is less than 40% on the right hand and foot, while the same value is 2.4% higher on the left hand and foot. The proportion of the loop pattern for the left hand is about 4% higher than for the right. However, in the case of the whorl pattern, the difference is not significant, and the arch pattern occurs at an equal ratio.

With regard to the middle finger and the third toe, it should be noted that the correspondence of the papillary ridge patterns is about 7% higher for the left hand-foot pair than for the right side. The proportion of the loop pattern is also about 5% higher on the left hand and foot compared to the right. However, the incidence of whorl and arch patterns are almost the same for hands and feet on both sides, differing by one percentage point.

In the case of the ring finger and the fourth toe, there is a difference of about 2.5% between the right hand and the left hand, in favour of the right. However, the incidence of ridge patterns varies. The loop pattern dominates the left hand-foot pair by about 5% compared to the right side. In the case of the whorl pattern, however, the correspondence is about 4% higher for the right hand-foot pair, compared to the left. The arch pattern is more represented on the right hand-foot, to the extent of about 2.5%.

With regard to the little finger and toe, it should be noted that the correspondence of the ridge patterns on the fingers and toes of the right hand is about 4% greater than that of the left hand-foot pair. The loop pattern occurs equally on the right and left hand and foot. Whorl pattern was not observed on either hand-foot pairs and the proportion of arch pattern is about 4% higher on the right hand.

From the results of the study, it can be concluded that the participants in this study had more whorl patterns on the third toe than loops and no whorl patterns were detected on the small toe. I. A. Anishenko's claim that the whorl pattern is less common on the toes than the loop pattern was also confirmed in the comparison of the left and right toes of the study participants. Regarding the relationship between the loop pattern and the arch pattern, it was noticeable that the little toes (both left and right foot) had

a more dominant arch pattern. For the other toes, the loop pattern was prevalent. In this respect, the authors must also concur with the corresponding claims by I. A. Anishenko.

Regarding finger analysis of both hands, it must be concluded that for the study participants loop pattern dominated, followed by the whorl pattern and then the arch pattern, which appeared several times less frequently than loop and whorl pattern on both hands.

In the footprints of the sole of the foot, the upper sections of the ridges that have formed can be traced and in which the most noticeable papillary ridges have an arch pattern. The study revealed that the thumb and the big toe have mostly developed a loop ridge pattern, less frequently a whorl pattern and minimally an arch pattern.

In several cases, it was observed that the pattern of the papillary ridges was the same on four or three fingers of both hands, based on common features (e.g., the loop pattern on four fingers and the whorl pattern on one). No matches were found for the same hand and foot – there were differences in the patterns of papillary ridge patterns of individual toes (for example, if four fingers on the right hand had a loop pattern and one finger a whorl pattern, the corresponding toes of the same foot did not have the same papillary ridges). Therefore, it can be concluded that the participants in this study did not show identical traces of papillary ridges on the fingers and toes.

However, the authors do not claim the absolute truth of this study that such coincidences could not occur in some people, on the basis of the general characteristics of papillary ridges of the skin. It should be noted that while the general characteristics are elements of identification, the special characteristics of the papillary ridges are more significant. As the aim of this study excluded identification of specific features of the papillary ridges, no such study was performed.

As a result of the study, it can be stated that based on the analysis of general characteristics, the patterns of the fingers and toes of the matching hand-and-foot pairs did not have a 100% correspondence.

This research is funded by the Latvian-Ukrainian Joint Programme of Scientific and Technological Cooperation Project (2021) "Open Educational Resource: Forensic Science", Project No. LV-UA/2021/3.

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