

Article

# Functional Asymmetry and Fingerprint Features of Left-Handed and Right-Handed Young Yakuts (Mongoloid Race, North-Eastern Siberia)

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**Abstract:** An ethnically homogeneous group of Yakuts (Mongoloid race, Northeast Asia), aged 18–31, was studied to characterize the diversity of particular features between left- and right-handed individuals. A total of 52 left-handed (32 women and 20 men) and 100 right-handed (50 women and 50 men) individuals were studied. Testing included two sets of questions and tasks, dynamometry of the right and left hand, and fingerprint analysis. Left-handed and right-handed people were found to differ in functional asymmetry of psychophysiological and motor reactions. Right-handers were characterized by higher intragroup similarity, while, among left-handers, greater dispersion of these traits was observed. Asymmetry in hand grip strength was less pronounced in the left-handed people than in the right-handed; this difference was statistically significant, and the difference was greater in men than in women. This suggests that the non-dominant hand in the left-handed people was subjected to a greater load and indicates the forced adaptation of the left-handed people to “dextrastress”. No significant difference between sexes was found when analyzing fingerprint patterns. Left-handers had arches significantly more often than right-handers. Radial loops were most often found on the index finger, and, in the left-handers, their occurrence was significantly higher on three to five fingers of the left hand compared with the right-handers. The levels of fluctuating asymmetry in left-handers and right-handers were similar.

**Keywords:** anthropology; handedness; dermatoglyphics; fingerprints; functional asymmetry; fluctuating asymmetry

## 1. Introduction

The development of bilateral symmetry, along with the capability of adaptation to a rapid change in environmental conditions during movement, contributed to increasing “biological reliability”, i.e., the development of paired organs, one of which is capable of partially assuming the function of its partner if the latter is lost due to injury. It is believed that the huge biological significance of bilateral symmetry contributes to its maintenance at a stable level by natural selection, and yet, in nature, there are no perfectly symmetrical structures [1]. Many papers are devoted to the problem of maintaining the symmetry of bilateral structures and the reasons for deviation from it. In particular, the classical work by Van Valen [2] shows three types of deviations from the perfectly symmetric state: directional asymmetry, anti-symmetry, and fluctuating asymmetry. The first two types of asymmetry are strictly hereditary, while the third type reflects the modulating effect of the environment on the developing organism [1,3–5]. However, no classification can fit the whole range of various phenomena into a rigid framework, and one such example is the manifestation of asymmetry (sensory and motor) in

humans. In most individuals, there is greater development of the organs on the right side of the body, with a smaller number of certain organs developed on the left—this type of asymmetry in humans is sometimes considered directional asymmetry [6] since, for this type of asymmetry, the manifestation of a feature on one side excludes its manifestation on the other side. However, it is necessary to realize that directional asymmetry is not only strictly determined genetically but is also characterized by the negative relation of the manifestation of the feature on different sides of the bilateral structure. On the other hand, in humans, not only is there a different degree of dominance observed in one structure over another, but there is also the phenomenon of ambidexterity, in which the feature is developed on both sides to virtually the same degree. There is still no consensus on the nature of left-handedness inheritance. The first studies in this direction gave reason to believe that the inheritance of handedness is ruled by Mendel's laws, and, in this vein, a simple model of monogenic recessive inheritance was assumed. However, this model does not explain the fact that, according to various sources, from 45% to 54% of children born to two left-handed parents are right-handed [7]. V.A. Geodakyan [8] points out that among the children of two right-handed parents, 2% are left-handed; if one of the parents is left-handed, 17% of the children are left-handed; if both parents are left-handed, the figure is 46%.

In light of these findings, in the second half of the 20th century, a number of more complex models of the inheritance of handedness were proposed, such as the right shift theory [9] and polygenic inheritance involving modifier genes [10,11]. These models have both supporters and critics, but their positive aspect is that they account for the modulating influence of the environment.

Thus, left-handedness is traditionally associated with the effect of three groups of factors: genetic, environmental (including cultural), and pathological. Handedness is a product of a multifaceted biosocial developmental process that begins prenatally and continues into adulthood, and although right-handedness predominates, handedness varies continuously across the population [12].

The study of left-handedness is complicated by the fact that, on one hand, in a number of cases, we observe “concealed left-handedness” due to the pressure of a “right-handed environment”, while on the other hand, some cases of left-handedness represent not a genetically conditioned result but the so-called compensatory left-handedness associated with injuries, where the function of the dominant hand is transferred to the intact structure.

McManus [13] supposes that the percentage of left-handedness in humans is constant at about 10% and has apparently not changed since the Neolithic. Raimond et al. [14] estimate a similar proportion—about 10–13%. However, the percentage of lefties reported in different studies varies. For example, at the end of the 20th century, Ravich-Scherbo et al. wrote that left-handed people make up an average of 5% of Russia's population [7]. G. McManus [13] believes that there are ethnic differences in the proportion of handedness, and this variation is related to geographical differences. Left-handedness is generally most common in White, Asian, and Hispanic populations. Geographical differences and historical differences primarily reflect changes in gene frequency rather than direct social pressure [13]. However, there is the opinion that the number of people who write with their right hand is determined not only by genetic predisposition but also by social pressure (that is, by the extent to which the society allows the individual to be unique) [15]. This is why countries where, until recently, this pressure was the highest also had the lowest percentage of left-handedness. For example, in Japan, the frequency of left-handed people was 0.9–3.0%. In countries with lower social pressure in this area, the rate is much higher: in Europe, according to different estimates, 7–9.5% of the population is left-handed; in the United States, figures as high as 12% are reported. Until recently, in many countries, there was a practice of retraining left-handed children, and as pressure from the environment lowered, the number of people writing with their left hand noticeably increased to 10–12% in the 1980s and 1990s [16]. This practice of retraining was abolished in Russia only in 1985 [17].

Left-handed people often have difficulties operating items designed—due to their predominance in society—for right-handers, with such items including various tools, instruments, apparatuses, buttons on household appliances, and door handles, as well as the process of writing in most cultures. As a result, throughout their lives, left-handed people experience dextrastress as a result of the necessity

to adapt to a world of right-handers. Left-handedness does not disappear, but the aggressiveness of the right-handed environment forces left-handed people to adapt to it, sometimes with great difficulty. Left-handers more often than right-handers suffer from borderline mental disorders, as well as mental illnesses (schizophrenia, epilepsy), and they have higher levels on psychological scales of “neuroticism”, “psychoticism”, and “depression” [18]. When left-handed children are forcibly taught to switch their preferred hand, such disorders as stuttering, strabismus, dyslexia, neuroticism, and incontinence are often observed [19,20]. Left-handed students often differ from right-handers in their formation of memories, mental strategy, and the specifics of emotional manifestations; the main problems experienced by left-handed students in school include restlessness, neuroses, and manifestations of emotional lability [21]. Handedness is associated with functional lateralization for cerebral dominance and may also be associated with various types of psychopathology, and some studies [13,22] have linked handedness and brain asymmetry to neurodevelopmental disorders, such as dyslexia and schizophrenia. Another study [23] reveals an elevated frequency of immune disease, migraine, and developmental learning disorders in left-handed individuals and their families compared with controls. An assumption made in [24] is that the fact that left-handedness occurs at a low frequency indicates that some evolutionary costs could be associated with left-handedness.

On the other hand, in some activities, left-handers have an advantage, as demonstrated by their engagement at high percentages in tennis, boxing, and other sports associated with competitive hand actions [25–27]. The higher proportion of left-handed individuals in interactive sports (reflecting some fighting elements), reaching 50% in some sports categories, but not in noninteractive sports, is consistent with the fighting hypothesis [14]. The maintenance in the population of the constant handedness polymorphism could be a testament to the fact that, despite the difficulties adapting to a right-handed world, lefties have some advantages that help in survival [14].

The increasing number of left-handed students dictates the need for special research on their adaptation to the right-handed world. A comprehensive study of the problem from psychological, pedagogical, medical, physiological, biological, and social points of view will advance the analysis of the causes of intrapopulation diversity, identification of the most effective diagnostic features, and development of a set of measures to reduce dextrastress in left-handed people.

Difficulties in studies comparing right-handed and left-handed people are connected to the above-mentioned specifics of phenotype development: the variability in psychophysiological reactions, the significant modulating influence of the environment, and concealed left-handedness. The methods of testing can vary considerably among different researchers. The effectiveness of interviews and surveys in such studies is evaluated and interpreted differently by different researchers. For example, among the congenital forms of psychophysiological reactions often used for assessment are such reactions as hand clasping, arm folding, and applauding [28–33]. Ocular dominance is also studied as a factor [34]. Yet, the results of these tests can vary significantly. It is very likely that the differences among different authors in their interpretation of the results based on hand clasping and arm folding stem not so much from handedness as they do from interpopulation differences.

One of the convenient tools in anthropological research is dermatoglyphics. Fingerprint and palm patterns can be used in population and racial studies, and repeated attempts have been made to find dermatoglyphic markers of handedness, but the results of different researchers are ambiguous [33,35–46].

In addition to its use in the analysis of dermal patterns in different ethnic and intrapopulation groups, dermatoglyphics has recently been widely applied to assessing fluctuating asymmetry (FA) levels to determine developmental stability. We have already mentioned above that this type of asymmetry reflects the influence of the environment on developing structures, and as a result, it can serve as an indicator of environmental stress and the general co-adaptation of the genome [1,3–5]. Investigations of FA in human subjects do not always give definitive results [6], and, in some studies, the authors concluded that developmental stability could not be estimated by the value of FA, because it poorly reflects the influence of the environment [47]. Ten Broek et al. [48] believe that limb FA

is mainly a good indicator for developmental instability only in the case of severe perturbations of development, and FA does not reflect the slight divergences from the normal path of development. Van Dongen [49] supposes that behavioral lateralization may distort the results of the FA assessment. Therefore, the choice in features for analysis is of great importance.

FA is used to assess the influence of maternal stress on the children's developmental stability in the human population as a risk marker for developmental disorders [50,51]. Many investigations are devoted to the evaluation of FA as it relates to various mental disorders, such as autism and schizophrenia [52–56]; cleft lip [57,58]; and different diseases, such as diabetes, hypertension, multiple sclerosis [59], cancer [60], hormone disorders [61], and kidney diseases [62].

It should be noted that the results are not always clear [59,62]. In some cases, researchers have noted that the markers of disorders in diseases may not be the actual FA level but rather the changes in the incidence and dermatoglyphic patterns [58,63–66]. We tend to agree with Kaur and Batra [67] that clinical diagnosis should not be based on dermatoglyphic features alone, because, due to the great natural variation found in print patterns, no single feature is specific to a particular disease.

The goal of our studies was to (1) evaluate the effectiveness of different testing approaches and the use of dermatoglyphic indicators to identify left-handed people and (2) assess the developmental stability of left-handed and right-handed people by establishing the level of fluctuating asymmetry of the fingerprints of a group of Yakuts (Mongoloids, Northeast Asia).

The Yakuts (or Sakhas) from the Republic of Sakha are of particular interest because they contrast with other populations from Siberia in many respects. The Yakuts are considered the most remarkable example of northward expansion into Siberia. These semi-nomadic cattle-farmers contrast especially strikingly with the surrounding Siberian populations in their Turkic language and their horse- and cattle-breeding economy. Archaeological data currently agree that the appearance of the Yakut culture was around the 14th century A.D. [68,69].

Recent population genetics data tend to support a dual origin for the maternal lineage of the Yakuts and intermixture with the Tungus and demonstrate that the paternal lines observed today result from a pronounced bottleneck that led to the restriction of this lineage in the Yakut population [69]. Since it has been repeatedly mentioned above that both psychophysiological reactions and dermatoglyphic features are subject to high interpopulation variability, it is of interest to consider these features in a relatively small ethnicity that inhabits a vast area that is much farther north of the original area.

## 2. Materials and Methods

The material for research was collected from among the population of Yakutsk (Russia, East Siberia). The studied group was homogeneous in ethnic composition, i.e., Yakut young people aged 18–31 who were students and postgraduates of the North-Eastern Federal University. The average age of the subjects was 21.5 years. The study did not include older people because the Russian pedagogy for a long time was dominated by the opinion that left-handers should be retrained; therefore, the proportion of left-handers among the older population is very low, and among the right-handed people in this subpopulation, a fraction of them are retrained left-handers [15,17,70]. Children of school age were not covered by the research because it has been shown that some motor reactions can change with age [33].

A total of 52 left-handers (32 females, 20 males) and 100 right-handers (50 females and 50 males) were examined. The main criterion for distinguishing between right- and left-handedness was self-identification and preferential use of the right or left hand during manual operations. To exclude compensatory left-handedness, only physically healthy individuals who were not subjected to handedness retraining as children were examined. The testing was carried out using two sets of questions to confirm the preference for using the left or right hand, the dynamometry of the left and right hands, and fingerprint analysis. All subjects provided informed consent to participate in the study.

The first set of tests included six tasks, which were based on the analysis of hereditarily fixed motor reactions in order to determine the dominant cerebral hemisphere [33,70].

- Hand clasping;
- Arm folding;
- Applauding;
- Untying knots on a lace;
- Eye preference;
- Drawing of circles, squares, and triangles simultaneously with the right and left hands.

This complex of tasks, with some degree of assumption, we refer to below as psychophysiological testing. Tasks 1–3 were performed in triplicate: during conversations with the subjects, they were asked three times (with different time intervals) to perform a certain action—clasp their hands, applaud, and fold their arms—and then the average was taken. For the hand-clasping task, the subject was asked to clasp their hands with interlaced fingers (Figure 1) to see the which hand's finger was on top; this was repeated three times, without attracting the attention of the subject and alternating with other tasks. For arm folding (Figure 1), we noted which forearm was on top; this also was repeated three times, as with the first task, without attracting the attention of the subject. When performing the task of applauding, the subject was asked to applaud, to see which hand was above. The action also was repeated three times, without attracting attention. It is believed that when performing these tasks, fingers, the forearm, and the hand of the dominant hand are above [70].



**Figure 1.** Tasks no. 1–3 of the complex of psychophysiological tests.

During the task of untying three simple knots on one lace, we observed which hand the subject used. The average of three actions was taken as the result. During the test for determining the dominant eye, the subjects were asked to keep both eyes open while looking through a hole in a sheet of paper 1 cm in diameter to focus on a point 3–4 m away from them. Then, while staying in the same position, they were asked to close their left and right eyes alternately. The eye that saw the point was considered dominant. Preliminary studies of the determination of the dominant eye showed 100% individual reproducibility of the results, so this test was carried out once per individual.

With the simultaneous drawing of circles, squares, and triangles, the test subject was given two pencils and asked to draw a circle, a square, and a triangle simultaneously with both hands without

taking the pencil from the paper. The pattern was analyzed for the accuracy of the lines and contours of the three geometric shapes.

At the first stage, the results of complex no. 1 were evaluated according to the ratio of the answers (Table 1), and when compared with the results of test complex no. 2, each task of complex no. 1 was assigned a number of points: 3 points for right-handedness, 1 point for left-handedness.

**Table 1.** Scheme for determination of handedness.

Tests	Classification Principle	Result	Outcome
Complex 1	Answer ratio. Tendency for right-handedness/left-handedness	6/0	Complete right-hander
		5/1	Moderate right-hander
		4/2	
		3/3	Ambidextrous
		2/4	Moderate left-hander
		1/5	
0/6	Complete left-hander		
Complex 2	Score: 3 points—right-handed, 2 points—neutral, 1 point—left-handed	33–36	Complete right-hander
		27–32	Moderate right-hander
		22–26	Ambidextrous
		16–21	Moderate left-hander
		12–15	Complete left-hander

During the second stage of testing, right- or left-handedness was determined according to the preference of one hand over the other when performing manual actions on the basis of a questionnaire. Twelve general and sports habits were selected: Which hand do you draw with? Which hand do you throw a ball with? In which hand do you hold the racket in tennis, squash, etc.? In which hand do you hold a toothbrush? In which hand do you hold a knife when you cut something (without a fork)? In which hand do you hold a hammer when you strike nails? When you light a match, which hand holds it? With which hand do you use an eraser? Which hand do you use to take the top card off a deck of playing cards? Which hand do you use to put a thread through the eye of a needle? In which hand do you hold a fly swatter?

The answers were weighted on a 3-point scale: 3 points for right-handed, 2 points for neutral, and 1 point for left-handed. Handedness was classified by the sum of points according to the scheme given in Table 1. In addition, we evaluated the test results of each individual by calculating the average value for complex 1 and complex 2. The score ranged from 3 points (absolute right-hander) to 1 point (absolute left-hander). A score of approximately 2 points was characterized as ambidextrous.

To determine the functional asymmetry in the performance of the test tasks, we calculated the asymmetry coefficient using the formula below [54]:

$$TK_{as} = \frac{T_R - T_L}{T_R + T_L + T_0} \quad (1)$$

where  $TK_{as}$  is the asymmetry coefficient;  $T_R$  is the number of test tasks with dominance of the right side;  $T_L$  is the number of test tasks with dominance of the left side;  $T_0$  is the number of test tasks without pronounced dominance of either side. A positive  $TK_{as}$  indicates dominance of R reactions, a negative value indicates the dominance of L reactions, and a  $TK_{as}$  near 0 characterizes ambidexterity.

Dynamometry was performed with a dynamometer (“MEGEON-34090” with an accuracy of 0.1 kg) thrice for each hand, and the average was calculated. The functional asymmetry of compression force was calculated using the formula:

$$EK_{as} = \frac{E_R - E_L}{E_R + E_L} \quad (2)$$

where  $EK_{as}$  is the asymmetry coefficient;  $E_R$  is the right hand's compression force;  $E_L$  is the left hand's compression force. A positive value of  $K_{as}$  indicates dominance of R reactions, and a negative value indicates dominance of L reactions.

In dermatoglyphic studies, three types of fingerprint patterns were distinguished—whorls (W), ulnar and radial loops (UL, RL), and arches (A)—in addition to ridge count. The ridge count was measured as the number of ridges intersected by a straight line drawn from the delta to the center of the pattern. Ridges were counted from two sides. In the arch pattern, the ridge count was taken to be zero. The sum of the ridges on the 5 fingers of one hand was considered to be the total ridge count; the sum of the ridges on the 10 fingers of both hands was recorded as the summary ridge count.

To assess the asymmetry of different types of fingerprint patterns, the delta index was calculated separately for right and left hands using the same formula, and the occurrence of asymmetric manifestations of the trait was calculated using the following formula:

$$D_i = \frac{L + 2W}{L + W + A} \quad (3)$$

where  $D_i$  is the delta index,  $A$  is the number of arches,  $L$  is the number of loops, and  $W$  is the number of whorls.

The level of the fluctuating asymmetry of different types of fingerprint patterns was estimated by the occurrence of asymmetry manifestations per individual, with each asymmetric feature given a weight of 1 point and each symmetric feature assigned a weight of 0 points. We used the occurrence of the fluctuating asymmetry manifestations (OFAM) to measure the individual FA level. OFAM was calculated as the ratio of asymmetric features to the total number of features examined and expressed as a decimal fraction [71,72].

$$OFAM = \frac{A}{m} \quad (4)$$

where OFAM is the occurrence of the fluctuating asymmetry manifestation;  $A$  is the number of asymmetric features;  $m$  is the total number of the examined features—in this case,  $m = 5$  (the number of fingers on one hand). Thus, hypothetically, we can characterize each individual by an OFAM value from 0 (if each fingerprint type is the same on the five fingers of both hands) to 1 (if fingerprint types differed in all finger pairs).

Fluctuating asymmetry of the ridge count was calculated using the formula:

$$FA = ABS\left(\frac{RCR - RCL}{RCR + RCL}\right) \quad (5)$$

where  $FA$  is fluctuating asymmetry;  $ABS$  is the absolute value;  $RCR$  is the ridge count of the right hand;  $RCL$  is the ridge count of the left hand.

Asymmetry of fingerprints was calculated using the formula:

$$FP_{as} = \frac{O_R - O_L}{O_R + O_L} \quad (6)$$

where  $FP_{as}$  is fingerprint directional asymmetry,  $O_R$  is the occurrence of fingerprint patterns on the right hand, and  $O_L$  is the occurrence of fingerprint patterns on the left hand. A positive  $FP_{as}$  value means a more frequent pattern on the right hand, and a negative value is a higher frequency on the left hand.

For the statistical treatment of the data, standard methods were used. As a measure of FA at the population level, the arithmetic mean of OFAM was used. For a pairwise comparison of samples, we used Student's  $t$ -test; for the comparison of data series, Spearman's rank correlation coefficient was applied.

### 3. Results and Discussion

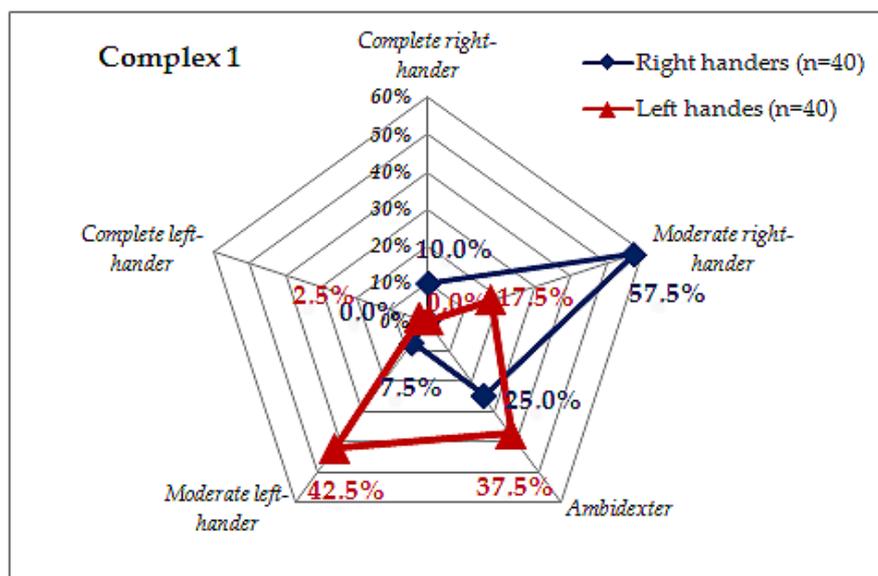
The results of psychophysiological testing showed no significant differences within the groups of either females or males, and at the same time, a wide spread of the results was observed for both left-handers and right-handers. For tasks with triple repetitions (tests 1–4), a high degree of reproducibility was noted: in most cases, the subjects were more comfortable with only one position of their hands, and when asked to assume the pose again but place the other hand on top, most subjects were confused and could not do this on the first attempt, as the instructed pose was uncomfortable for them. There were few cases in which it did not matter which hand was above. The drawing task revealed that, in most cases, right-handers drew clearer pictures with the right hand, and left-handers produced better pictures with the left hand. Three exceptions were recorded, two left-handers and one right-hander, whose pictures drawn with either hand were basically identical.

Among the right-handers, the dominance of the right hand and the right eye when performing the complex of tasks was 67%, whereas, among the left-handers, only 45% showed L-reactions and 37% showed an inclination toward ambidexterity (Figure 2). There were no differences between sexes in either group during task performance (Table 2). The assessment of handedness in points showed that the average score of right-handers was 2.4 (moderate right-handedness), and left-handers only scored 1.9, i.e., the results were very close to a score indicating ambidexterity. The differences between left-handers and right-handers reached a statistically significant level (Table 2).

A more detailed analysis showed that only questions 5 and 6 significantly correlated with the handedness of individuals. For the dominant eye, Spearman's correlation coefficient was 0.56; for drawing geometric figures, it was 0.98 ( $p < 0.001$ ). These two components were the main contributors to the correlation between the results of this complex of tests and handedness (0.60,  $p < 0.05$ ). Additionally, it should be noted that the two aspects correlated with each other, also statistically significantly (0.60,  $p < 0.05$ ).

Earlier, we mentioned that for the first two tasks of this complex, there is ambiguous information on the association between the trait and handedness [33]. Rhoads and Damon [28] suppose that hand clasping and arm folding are not associated with one another, and arm folding is not associated with either handedness or sex; however, they do show an age association. Kobylansky et al. [29] note that L-tendencies in both actions are pronounced in left-handers and ambidextrous individuals, while right-handers demonstrate right hand-clasping and left arm-folding. Also, although the manifestations of these traits vary within each group (left-handed, right-handed, and ambidextrous people), these authors believe that these traits are suitable for detecting left-handedness. However, they note that there are interpopulation differences in the manifestations of the traits. Downey [30] and Kawabe [31] also confirmed a relationship between handedness and hand clasping, but Beckman and Elston [32] denied any relation between these two traits. A. Poliukhov [33] reported that the distribution of R- and L-types of hand clasping in the population is about 50%, dependent on age, and unlikely to be genetically determined, whereas arm folding has a weak association with handedness and asymmetry in fingerprints. A. Dvirsky [73] used three tests for comparing left-handers and right-handers: hand clasping, arm folding, and eye preference. According to him, there is no difference in arm folding between left-handers and right-handers, whereas for eye preference and hand clasping, statistically significant differences are observed. It is very likely that the differences among different authors' interpretations of results for hand clasping and arm folding stem not so much from handedness as they do from interpopulation differences.

Our results show that both hand clasping and arm folding are loosely correlated between each other and with handedness. We believe that although these traits are widely used in tests for handedness and are relatively suitable for group studies, they are not suitable for the assessment of handedness in individuals.

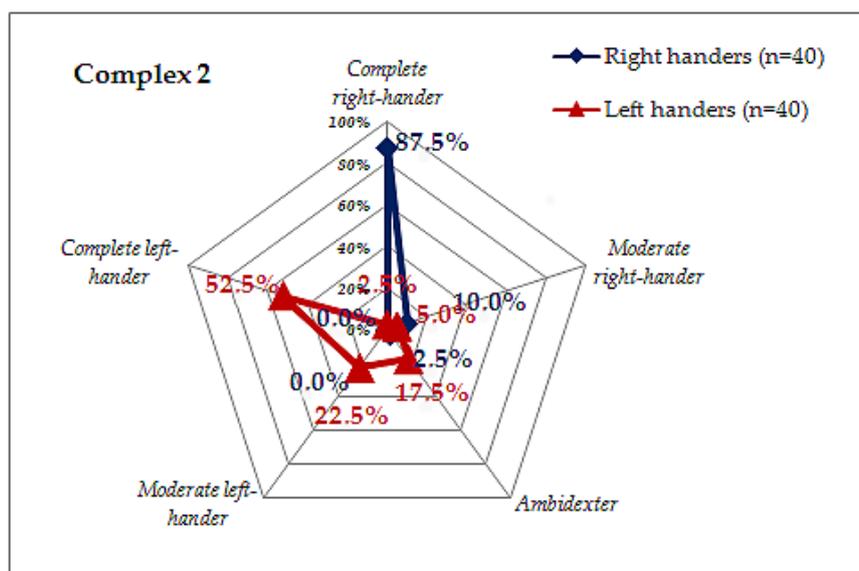


**Figure 2.** Percentage of individuals with dominance of R- and L-reactions according to the results of psychophysiological testing.

**Table 2.** Numerical scores of psychophysiological and motor reactions of left-handers and right-handers.

Tests	Sex	Sum Score		Average Score	
		Right-Handers	Left-Handers	Right-Handers	Left-Handers
Complex 1	Males	14.30 ± 0.53	11.33 ± 0.46	2.4 ± 0.09	1.9 ± 0.08
	Females	14.42 ± 0.48	10.90 ± 0.51	2.4 ± 0.08	1.8 ± 0.08
	Average	14.36 ± 0.35	11.12 ± 0.34	2.4 ± 0.06	1.9 ± 0.06
	Limit	9.00–18.00	6.00–16.00	1.5–3.0	1.0–2.7
	Mod value	16.0	10.7	2.7	1.8
	Difference between right-handers and left-handers, Student's <i>t</i> -test				
Complex 2	Males	34.00 ± 0.58	17.60 ± 1.53	2.8 ± 0.05	1.5 ± 0.13
	Females	35.10 ± 0.35	16.75 ± 1.09	2.9 ± 0.03	1.4 ± 0.09
	Average	34.55 ± 0.35	17.18 ± 0.93	2.9 ± 0.03	1.4 ± 0.08
	Limit	26.00–36.00	12.00–34.00	2.2–3.0	1.0–2.8
	Mod value	36.0	12.0	3.0	1.0
	Difference between right-handers and left-handers, Student's <i>t</i> -test				

The results of testing general and sports skills showed slightly different results: among the right-handed people, the overwhelming majority demonstrated R-reactions, 2.5% showed ambidextrous reactions, and no L-type reaction was observed (Figure 3). Among the left-handed people, the intensity of handedness was lesser than that among the right-handed, so, the percentage of R-reactions and ambidexterity was higher (Figure 3). The average score for right-handers fell into the category “complete right-hander”, while, for left-handers, their average was classified as “moderate left-hander”, i.e., the numerical scores also indicated that L-reactions in left-handers were weaker than R-reactions in right-handers. Overall handedness scoring by this complex of tests gave better results than the first set of tests. The average score of right-handers was 2.9, which corresponds to the assessment of “absolute right-handers”, and left-handers scored an average of 1.4, i.e., moderate left-handers. A correlation of the results of the second test series with handedness was also statistically significant, and the significance level was higher than that for complex 1 (0.86, *p* < 0.001).



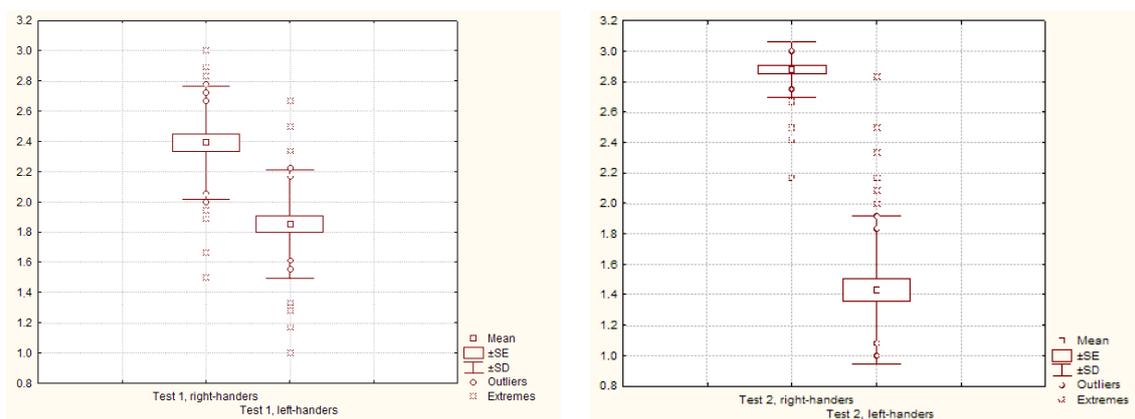
**Figure 3.** Percentage of individuals with dominance of R- and L-reactions, evaluated by general and sports skills.

Evaluation of the asymmetry of motor reactions based on the results of both test complexes showed statistically significant differences between right-handed and left-handed people (Tables 2 and 3). According to the results of psychophysiological testing, the asymmetry coefficient among the right-handers was +0.40 (dominance of the right hand), among the left-handers it was  $-0.14$  (slight dominance of the left hand), and, according to general and sports skills, it was +0.88 and  $-0.53$ , respectively. The intensity of R-reactions in right-handers with both methods of calculation was higher than that of L-reactions in left-handers. It should be noted that the spread of signs in the group of left-handers was higher than that of right-handers (Figure 4).

**Table 3.** The asymmetry coefficient ( $TK_{as}$ ) of psychophysiological and motor reactions of left-handers and right-handers.

Test	Sex	Handedness		Student's <i>t</i> -test
		Right-Handers	Left-Handers	
Complex 1 $TK_{as1}$	Males	$0.38 \pm 0.10$	$-0.09 \pm 0.07$	$3.87 p < 0.0004$
	Females	$0.43 \pm 0.08$	$-0.19 \pm 0.09$	$5.24 p < 0.0001$
	Average	$0.40 \pm 0.06$	$-0.14 \pm 0.06$	$6.48 p < 0.0001$
Complex 2 $TK_{as2}$	Males	$0.81 \pm 0.05$	$-0.53 \pm 0.13$	$9.81 p < 0.0001$
	Females	$0.95 \pm 0.02$	$-0.53 \pm 0.10$	$13.91 p < 0.0001$
	Average	$0.88 \pm 0.03$	$-0.53 \pm 0.08$	$16.35 p < 0.0001$

A comparison of the two complexes of tests showed statistically significant correlations between their results (Spearman's rho 0.64,  $p < 0.0001$ ), but a more detailed analysis showed that the main contribution to this correlation from the side of the complex of psychophysiological reactions was made by tasks 5–6 (determination of the dominant eye and drawing of geometric figures), for which the correlation with the second complex was 0.87 and 0.69 with a high level of significance. On the other hand, for tasks 1–4, no significant association with complex 2 was found. The correlation between ocular dominance and handedness has been mentioned by other authors [34].



**Figure 4.** Scatter characteristics of handedness, as assessed by two complexes of tests.

The results of grip dynamometry showed, as one would expect, that on the whole, grip strength in right-handers was higher for the right-hand, and left-handers were stronger in their left hand (Table 4). Note that the difference between the left and right hand, both in absolute values and in asymmetry coefficient, was less pronounced in left-handed people than in the right-handed at a statistically significant level. In males, this difference was more pronounced than in females ( $p < 0.01$ , Table 4).

**Table 4.** Grip strength and the asymmetry of the grip strength ( $EK_{as}$ ) in left-handers and right-handers.

Sex	Right Hand M ± m	Left Hand M ± m	Limit	Coefficient of Variation	$EK_{as}$
<b>Right-handed</b>					
Males ( $n = 30$ )	44.63 ± 1.35	40.95 ± 1.40	29.37–56.10	10.18 ± 1.47	0.045 ± 0.010
Females ( $n = 30$ )	26.22 ± 0.56	24.53 ± 0.73	17.20–33.80	8.23 ± 1.21	0.036 ± 0.008
Sexual difference $EK_{as}$ , Student’s <i>t</i> -test				1.25, not significant	
<b>Left-handed</b>					
Males ( $n = 20$ )	39.68 ± 1.84	41.63 ± 1.71	24.40–55.07	9.94 ± 1.16	−0.012 ± 0.012
Females ( $n = 28$ )	24.63 ± 0.92	25.17 ± 0.90	14.83–37.27	10.37 ± 1.17	−0.026 ± 0.012
Sexual difference $EK_{as}$ , Student’s <i>t</i> -test				3.17, $p < 0.01$	

A comparison of the asymmetry of the grip strength with the results of the two test variants showed statistically significant correlations, even though their values were low: for the first complex, Spearman’s rank correlation coefficient was 0.41 ( $p < 0.0002$ ); for the second test series, it was 0.50 ( $p < 0.00001$ ).

#### 4. Fingerprint Analysis

For the analysis of fingerprints, we examined the distribution of the main types of patterns on the fingers of the right and left hand in left- and right-handed individuals, both separately for males and females and for both sexes together (Figure 5). The most frequent variants of the patterns were ulnar loops and whorls, and their distribution on the fingers was not uniform (Table 5). Whorls, both in right- and left-handed people, were observed most often on the first, second, and fourth fingers, less often on the third, and very rarely on the fifth finger. Ulnar loops were observed most often on the fifth finger and least often on the second finger. Radial loops were confined almost exclusively to the second finger, somewhat less often found on from the third to fifth, and never on the first. Arches were most often found on the second and third fingers, less often on the first and fourth, and very rarely on the fifth.

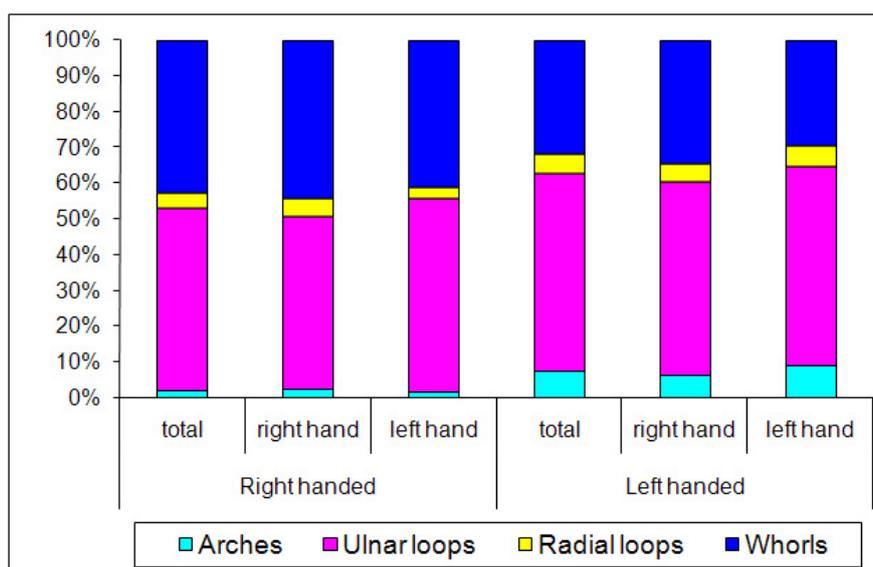


Figure 5. Percentage of the main types of patterns in left-handers and right-handers.

Table 5. Distribution of the main types of patterns on the fingers of left-handers and right-handers, %.

Patterns	Right Hand					Left Hand				
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
<b>Right-handed males</b>										
Arches	0.0	10.0	2.0	0.0	0.0	2.0	4.0	0.0	0.0	0.0
Ulnar loops	42.0	26.0	50.0	32.0	78.0	40.0	36.0	66.0	48.0	72.0
Radial loops	0.0	24.0	6.0	0.0	2.0	0.0	14.0	2.0	0.0	2.0
Whorls	58.0	40.0	42.0	68.0	20.0	58.0	46.0	32.0	52.0	26.0
<b>Right-handed females</b>										
Arches	2.0	4.0	4.0	4.0	2.0	2.0	6.0	6.0	0.0	0.0
Ulnar loops	50.0	30.0	50.0	40.0	82.0	54.0	30.0	52.0	54.0	86.0
Radial loops	0.0	20.0	0.0	0.0	0.0	0.0	14.0	2.0	0.0	0.0
Whorls	48.0	46.0	46.0	56.0	16.0	44.0	50.0	40.0	46.0	14.0
<b>Left-handed males</b>										
Arches	10.0	20.0	5.0	0.0	0.0	10.0	20.0	10.0	0.0	0.0
Ulnar loops	40.0	15.0	65.0	60.0	70.0	50.0	20.0	75.0	65.0	80.0
Radial loops	0.0	30.0	5.0	5.0	5.0	0.0	15.0	0.0	0.0	5.0
Whorls	50.0	35.0	25.0	35.0	25.0	40.0	45.0	15.0	35.0	15.0
<b>Left-handed females</b>										
Arches	3.1	12.5	9.4	3.1	3.1	6.3	15.6	15.6	9.4	3.1
Ulnar loops	50.0	31.3	62.5	56.3	84.4	40.6	25.0	59.4	62.5	84.4
Radial loops	0.0	12.5	0.0	0.0	0.0	0.0	15.6	9.4	3.1	6.3
Whorls	46.9	43.8	28.1	40.6	12.5	53.1	43.8	15.6	25.0	6.3

In general, the distribution of the patterns on the fingers of the right and left hand can be represented in Table 6.

**Table 6.** The level of occurrence of the main types of patterns in left-handers and right-handers.

Patterns	Hand	Reduction in Occurrence in Different Finger-Patterns									
											
<b>Right-handers</b>											
Arches	Right	II	>	III	≥	IV	≥	I	≥	V	
	Left	II	>	III	≥	I	>	IV		V	
Radial loops	Right	II	>	III	>	V	>	I		IV	
	Left	II	>	III	>	V	>	I		IV	
Ulnar loops	Right	V	>	III	≥	I	>	IV	>	II	
	Left	V	>	III	≥	IV	≥	I	>	II	
Whorls	Right	IV	≥	I	>	III	≥	II	>	V	
	Left	I	≥	IV	≥	II	>	III	>	V	
<b>Left-handers</b>											
Arches	Right	II	>	III	≥	I	>	IV	≈	V	
	Left	II	>	III	>	I	>	IV		V	
Radial loops	Right	II	>	III	≈	IV	≈	V	>	I	
	Left	II	>	III	≈	V	>	IV	>	I	
Ulnar loops	Right	V	>	III	≥	IV	>	I	>	II	
	Left	V	>	III	≥	IV	>	I	>	II	
Whorls	Right	I	>	II	>	IV	>	III	>	V	
	Left	I	>	II	>	IV	>	III	>	V	

**Table of Symbols:**

Fingers:		Occurrence	
I	Thumb	>	Higher
II	Index	≥	Higher or equal
III	Middle	≈	Approximately equal
IV	Ring		The pattern was not found
V	Little		

Phenetic diversity varied most significantly: the most common was a combination of two types of patterns: “ulnar loops + whorls” or “ulnar loops + radial loops”; among left-handers, they were found in 56% of the subjects, and among right-handers, they were in 58% of individuals. Somewhat less often was a combination of three patterns in one individual (38.5% and 27%, respectively). Very rarely were there cases of monomorphism—when all 10 fingers have a pattern of one type (ulnar loops or whorls)—it was found in 5.8% of left-handers and 13% of right-handers; the difference between left-handers and right-handers in this parameter, although considerable, did not reach a statistically significant level. Additionally, 2% of right-handers had a combination of all four types of patterns, whereas no left-handers had it.

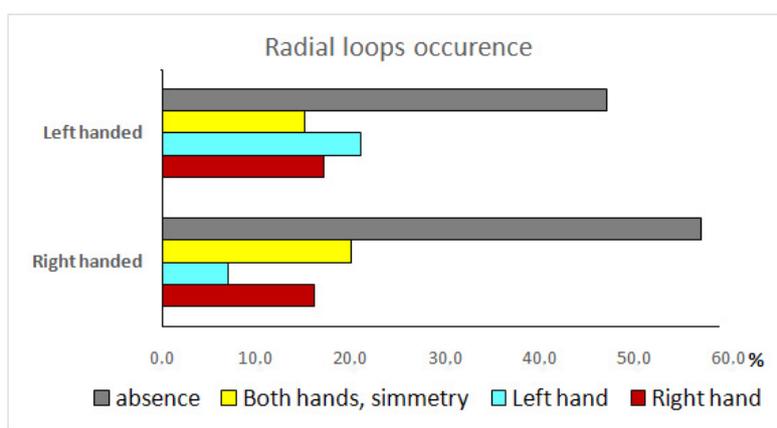
In our data, there were no statistically significant sex differences in pattern occurrence, and variability in the distribution of different patterns within the left-handed and right-handed groups was often higher than sex differences. The most widespread pattern in both groups was that of loops, which were registered at counts of 1–10 per individual in 90–97% of cases (Table 7). The more common loop variation was, as found in other studies, ulnar loops. In left-handers, they were found slightly more often than in right-handers, but the differences did not reach a statistically significant level (Table 7). The occurrence of loops in general—and ulnar ones in particular—was slightly higher in women than in men, but the differences were insignificant.

**Table 7.** Occurrence of different types of loops in left-handers and right-handers.

Sex, Handedness	Average Number of Loops per Individual			Individuals, % Occurrence
	Right Hand	Left Hand	Total	
<b>Loops, total *</b>				
Right-handed males ( <i>n</i> = 50)	2.52 ± 0.21	2.80 ± 0.24	5.32 ± 0.40	90.00
Right-handed females ( <i>n</i> = 50)	2.68 ± 0.25	2.92 ± 0.24	5.60 ± 0.46	94.00
Right-handed total ( <i>n</i> = 100) **	2.60 ± 0.16	2.86 ± 0.17	5.46 ± 0.30	92.00
Left-handed males ( <i>n</i> = 20)	2.95 ± 0.32	3.10 ± 0.32	6.05 ± 0.60	90.00
Left-handed females ( <i>n</i> = 32)	2.97 ± 0.23	3.06 ± 0.25	6.03 ± 0.43	96.88
Left-handed total ( <i>n</i> = 52) **	2.96 ± 0.19	3.08 ± 0.19	6.04 ± 0.35	94.23
<b>Ulnar loops *</b>				
Right-handed males ( <i>n</i> = 50)	2.20 ± 0.22	2.62 ± 0.22	4.82 ± 0.38	90.00
Right-handed females ( <i>n</i> = 50)	2.48 ± 0.24	2.76 ± 0.23	5.24 ± 0.44	94.00
Right-handed total ( <i>n</i> = 100) **	2.34 ± 0.16	2.69 ± 0.16	5.03 ± 0.29	92.00
Left-handed males ( <i>n</i> = 20)	2.50 ± 0.33	2.90 ± 0.30	5.40 ± 0.59	90.00
Left-handed females ( <i>n</i> = 32)	2.84 ± 0.22	2.72 ± 0.24	5.56 ± 0.39	96.88
Left-handed total ( <i>n</i> = 52) **	2.71 ± 0.18	2.79 ± 0.19	5.50 ± 0.33	94.23
<b>Radial loops</b>				
Sex, Handedness	Average Number of Loops			Occurrence on the Fingers 3–5
	Right Hand *	Left Hand *	Total *	
Right-handed males ( <i>n</i> = 50)	0.32 ± 0.08	0.18 ± 0.06	0.50 ± 0.11	0.06 ± 0.04
Right-handed females ( <i>n</i> = 50)	0.20 ± 0.06	0.16 ± 0.05	0.36 ± 0.09	0.02 ± 0.02
Right-handed total ( <i>n</i> = 100) **	0.26 ± 0.05	0.17 ± 0.04	0.43 ± 0.07	0.04 ± 0.02
Left-handed males ( <i>n</i> = 20)	0.45 ± 0.17	0.20 ± 0.09	0.65 ± 0.18	0.20 ± 0.11
Left-handed females ( <i>n</i> = 32)	0.13 ± 0.06	0.34 ± 0.15	0.47 ± 0.17	0.19 ± 0.10
Left-handed total ( <i>n</i> = 52) **	0.25 ± 0.08	0.29 ± 0.10	0.54 ± 0.13	0.19 ± 0.06
Difference between right- and left-handers, Student's <i>t</i> -test	Not significant	Not significant	Not significant	3.32, <i>p</i> < 0.001

\* Differences between all groups do not reach a statistically significant level. \*\* Differences between sexes within the group do not reach a statistically significant level.

At the individual level, radial loops were observed in 34.62% of left-handers and 30% of right-handers. It is necessary to point out the high intragroup variability: right-handers of both sexes were characterized by a common trend: a higher occurrence of radial loops on the right hand. Left-handers demonstrated two trends: in men, it was the same trend seen in right-handers—radial loops occurred more often on the right hand—while in women, radial loops were more often observed on the left hand (Table 7). However, the differences did not reach a statistically significant level in either the comparison by sex or by handedness. This lack of significance is why we considered it reasonable to examine the combined samples of left-handers and right-handers. By doing so, we observed a similarity in the occurrence of radial loops on the right hand of the right-handers and on both hands of the left-handers, while on the left hand of the right-handers, they were found much less often (Figure 6). Also, right-handers had radial loops mainly on the index fingers of both hands, while left-handers were characterized by a higher occurrence of this pattern on from the third to fifth fingers (Table 7). The analysis of the asymmetry of the distribution of radial loops on the right and left hands showed that, in general, the right-handed subjects were characterized by positive asymmetry of the distribution of this trait, i.e., by a higher occurrence on the right hand. For the left-handed subjects, the picture was more complex: in women, there was pronounced asymmetry, where an association of radial loops with the left hand was observed; in men, the distribution was almost uniform, with a somewhat greater occurrence on the right hand (Tables 7 and 8).



**Figure 6.** Distribution of radial loops on the hands of left-handers and right-handers.

**Table 8.** Directional asymmetry in distribution of radial loops and arches in left-handers and right-handers.

Handedness, Sex	Radial Loops FP <sub>as</sub>		Arches FPAs	
	<i>n</i>	<i>M</i> ± <i>m</i>	<i>n</i>	<i>M</i> ± <i>m</i>
Right-handed males	10	+0.53 ± 0.19	5	+0.50 ± 0.27
Right-handed females	8	+0.15 ± 0.22	7	+0.38 ± 0.53
Right-handers, total	18	+0.37 ± 0.15	12	+0.44 ± 0.29
Left-handed males	17	+0.30 ± 0.30	8	−0.20 ± 0.37
Left-handed females	13	−0.88 ± 0.52	8	−0.86 ± 0.46
Left-handers, total	30	−0.22 ± 0.31	16	−0.58 ± 0.31
Differences between left-handers and right-handers, Student's <i>t</i> -test		2.21 <i>p</i> < 0.05	2.40 <i>p</i> < 0.05	

The occurrence of whorls in left-handers and right-handers differed at a statistically significant level (Student's *t*-test 2.17, *p* < 0.05), where it was higher in right-handers (Table 9). Meanwhile, the occurrence of this type of pattern distribution between sexes was directly opposite to the occurrence of ulnar loops: whorls in men were more common than in women, but, overall, the prevalence was insignificant. Interestingly, the distribution of this pattern to all 10 fingers in men was more common than in women and was significantly different in left-handers and right-handers.

**Table 9.** Occurrence of whorls in left-handers and right-handers.

Sex, Handedness *	Average Number of Whorls Per Individual			Individuals, %	
	Right Hand	Left Hand	Total	Occurrence	On 10 Fingers
Right-handed men	2.32 ± 0.23	2.14 ± 0.24	4.46 ± 0.42	92.0	10.0
Right-handed women	2.14 ± 0.26	1.96 ± 0.24	4.10 ± 0.49	72.00	6.00
Right-handed total	2.23 ± 0.18	2.05 ± 0.17	4.28 ± 0.32	82.00	8.00
Left-handed men	1.70 ± 0.36	1.50 ± 0.36	3.20 ± 0.70	75.00	10.00
Left-handed women	1.72 ± 0.25	1.44 ± 0.27	3.16 ± 0.48	84.38	3.13
Left-handed total	1.71 ± 0.21	1.46 ± 0.21	3.17 ± 0.40	80.77	5.77
Differences between left-handers and right-handers, Student's <i>t</i> -test	Not significant	2.17 <i>p</i> < 0.05	2.17 <i>p</i> < 0.05	Not significant	12.33 <i>p</i> < 0.001

\* Sample size is given in Table 7.

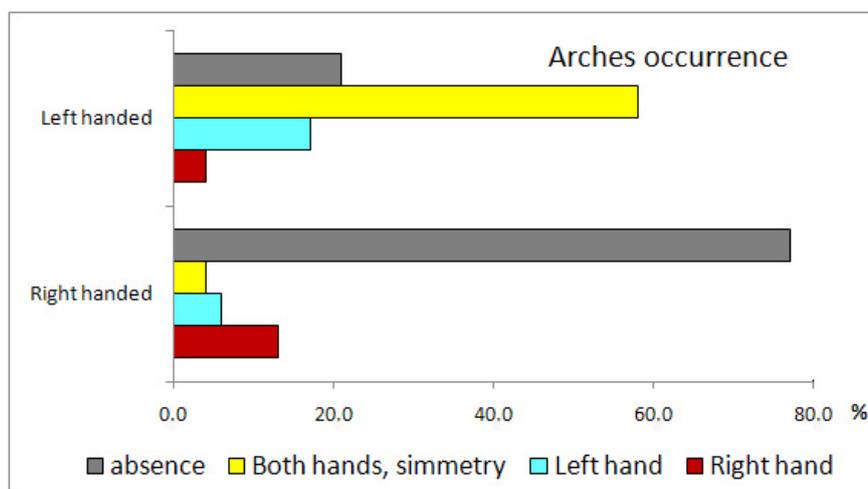
In left-handers, a lower occurrence of whorls was accompanied by a higher occurrence of arches. At the individual level, arches were observed in 23.08% of left-handers and 16% of right-handers. We propose that it is the occurrence of arches that is the most evident dermatoglyphic marker distinguishing between right-handed and left-handed people at the group level. Left-handers were observed to have a higher occurrence of arches on either hand, often on both hands simultaneously, as well as a high proportion of individuals who had three or four arches on the fingers of one hand

(Table 10, Figure 7). In the analysis of this pattern type, no sex differences within the groups were observed, while most of the differences between left-handers and right-handers were characterized by statistical significance (Table 10). Directional asymmetry in the distribution of this pattern type was positive in right-handers and negative in left-handers, with differences reaching a statistically significant level (Table 8). Similar results were obtained by L. Kerkadze et al. [42]. They noted that, in left-handers, arches were found almost twice as often as in right-handers, and they were mainly on the left hand, while whorls and loops were more often seen in right-handers. However, Sinha et al. [46] noted that left-handed samples were characterized by a high occurrence of modified radial loops and tented arch as compared with right-handers.

**Table 10.** Occurrence of arches in left-handers and right-handers.

Sex, Handedness *	Average Number of Arches Per Individual			On Both Hands	3–4 Arches on 1 Hand
	Right Hand	Left Hand	Total		
Right-handed men	0.14 ± 0.05	0.06 ± 0.03	0.20 ± 0.07	0.04 ± 0.03	0
Right-handed women	0.16 ± 0.08	0.10 ± 0.05	0.26 ± 0.10	0.02 ± 0.02	0
Right-handed total **	0.15 ± 0.05	0.08 ± 0.03	0.23 ± 0.06	0.03 ± 0.02	0
Left-handed men	0.35 ± 0.18	0.40 ± 0.18	0.75 ± 0.35	0.15 ± 0.08	0.05 ± 0.05
Left-handed women	0.31 ± 0.15	0.50 ± 0.19	0.81 ± 0.33	0.19 ± 0.07	0.13 ± 0.06
Left-handed total **	0.33 ± 0.12	0.46 ± 0.14	0.79 ± 0.24	0.17 ± 0.05	0.10 ± 0.04
Differences between left-handers and right-handers, Student's <i>t</i> -test	Not significant	2.74 <i>p</i> < 0.01	2.25 <i>p</i> < 0.05	2.57 <i>p</i> < 0.05	2.33 <i>p</i> < 0.05

\* Sample size is given in Table 7. \*\* Differences between sexes within the group do not reach a statistically significant level.



**Figure 7.** Distribution of arches on hands in left-handers and right-handers.

The results of earlier investigations by different researchers studying the distribution of fingerprint patterns on the hands were ambiguous. Some authors [35–38] believe that patterns of greater complexity are characteristic of the working hand, i.e., whorls are more frequent on the right hand in right-handers and on the left hand in left-handers. A. Poliukhov [33] notes that the predominance of whorls on the right hand is significantly associated with L-type motor reactions and believes that the R-type is associated with more whorls on the left hand. According to other authors, left-handers have patterns of greater complexity on the left hands, not on the right (but for separate fingers, just the opposite may be true) [39,40]. A number of researchers have noted that left-handed people, in general, have more arches and radial loops, but fewer whorls on their fingers [39,41].

The magnitude of the delta index (DI), in fact, is an average of the number of triradii, reflecting the ratio of patterns with two (whorls), one (loops), and no deltas (arches). In right-handers, a typical value

was found in representatives of the Mongoloid race that amounted to approximately 1.4 (Table 11), which indicates a relatively high occurrence of whorls, with the magnitude being the same for the right and left hands of representatives of both sexes. The delta index of left-handers was somewhat lower, and there was a difference in its value for the right and left hands (Table 11), but the difference between the hands did not reach a statistically significant level. At the same time, the differences between right-handers and left-handers were statistically significant (Student's *t*-test is 2.45,  $p < 0.05$ ), mainly due to differences in the left hand's DI (Table 11). This is due to the above-mentioned features of the distribution of patterns, especially that of arches.

**Table 11.** Delta index (DI) of left-handers and right-handers.

Handedness, Sex	Right Hand	Left Hand	Summary DI
Male right-handers ( $n = 50$ )	1.43 ± 0.05	1.42 ± 0.05	1.42 ± 0.05
Female right-handers ( $n = 50$ )	1.39 ± 0.06	1.36 ± 0.05	1.38 ± 0.05
Right-handers, total ( $n = 100$ )	1.41 ± 0.04	1.39 ± 0.04	1.40 ± 0.04
Male left-handers ( $n = 20$ )	1.27 ± 0.10	1.22 ± 0.10	1.25 ± 0.09
Female left-handers ( $n = 32$ )	1.28 ± 0.07	1.19 ± 0.08	1.23 ± 0.07
Left-handers, total ( $n = 52$ )	1.28 ± 0.06	1.20 ± 0.06	1.24 ± 0.06
Differences between left-handers and right-handers, Student's <i>t</i> -test	1.80, not significant	2.63, $p < 0.01$	2.45, $p < 0.05$

Some researchers [35,74] have noted sexual dimorphism in the occurrence of fingerprint patterns, and they believe that men are characterized by a higher occurrence of whorls, which is manifested in a significantly higher value of the delta index. On the contrary, in our samples, the differences between men and women were minute and did not reach a statistically significant level.

A number of researchers believe that finger patterns are distributed unevenly across the hands [35–38]. L. Kerkadze et al. [42] concluded that the symmetry of the dermal patterns of the hands of right-handers is higher than that of left-handers. In addition, there is the opinion that, in some cases, FA dermal patterns in left-handers are higher than that of right-handers [54]. To test this hypothesis, we estimated the FA of left-handed and right-handed individuals using several indicators.

The occurrence of the asymmetric manifestation of the patterns in right-handers was 0.27, and it was higher in men than in women ( $t = 2.08$ ,  $p < 0.05$ ) (Table 12). In left-handers, these figures are somewhat lower, with no gender differences (Table 11). It should be noted that the contribution of different fingers to the asymmetry of pattern distribution on the hands is different: the most symmetrical are the patterns on the thumb and little finger, although they vary between sexes, i.e., the highest asymmetry level of the thumb is characteristic of left-handed women, and for the little finger, the asymmetry is significantly higher in right-handed men (Table 12). The most asymmetrical patterns are found on the index finger, because this finger most often has a rare pattern type (radial loops and arches).

The magnitude of the ridge count, as well as phenetic variety, was observed to be subject to significant individual fluctuations, which is reflected in the magnitude of the error. In men, it was slightly higher than in women, but the differences did not reach a statistically significant level. Additionally, both groups tended to have a higher number of ridges on the dominant hand: the right hand in right-handers and the left hand in left-handers. However, again, the differences did not reach the level of significance (Table 13). Note that the level of fluctuating asymmetry of the ridge count in left-handers and right-handers was similar and, in the former case, it is even slightly lower (Table 13). There are different, sometimes contradictory opinions on this subject. Kimura, D., and Carson [45] believe that handedness does not affect the magnitude and asymmetry of the ridge count. At the same time, Nedz'ved' and Usoev [40] believe that the total ridge count for all fingers in left-handers is higher on the left (dominant) hand and higher in right-handers on the right one.

**Table 12.** Fluctuating asymmetry (FA) in the distribution of fingerprint patterns in left-handers and right-handers.

Hand, Finger	Males	Females	Total
	M ± m	M ± m	M ± m
<b>Right-handers</b>			
Thumb	0.18 ± 0.05	0.12 ± 0.05	0.15 ± 0.04
Index	0.48 ± 0.07	0.38 ± 0.07	0.43 ± 0.05
Middle	0.32 ± 0.07	0.22 ± 0.06	0.27 ± 0.04
Ring	0.36 ± 0.07	0.30 ± 0.07	0.33 ± 0.05
Little	0.24 ± 0.06	0.10 ± 0.04	0.17 ± 0.04
OFAM	0.32 ± 0.03	0.22 ± 0.03	0.27 ± 0.02
<b>Left-handers</b>			
Thumb	0.15 ± 0.08	0.25 ± 0.08	0.21 ± 0.06
Index	0.50 ± 0.11	0.34 ± 0.09	0.40 ± 0.07
Middle	0.20 ± 0.09	0.31 ± 0.08	0.27 ± 0.06
Ring	0.15 ± 0.08	0.31 ± 0.08	0.25 ± 0.06
Little	0.15 ± 0.08	0.13 ± 0.06	0.13 ± 0.05
OFAM	0.23 ± 0.04	0.27 ± 0.05	0.25 ± 0.03

OFAM: occurrence of the fluctuating asymmetry manifestation.

**Table 13.** Ridge count of left-handers and right-handers.

Group	Ridge Count			FA
	Right Hand	Left Hand	Total	
Females	71.15 ± 9.75	73.46 ± 3.71	144.60 ± 18.07	0.14 ± 0.04
Males	88.75 ± 8.97	74.44 ± 7.13	163.19 ± 16.14	0.10 ± 0.02
Right-handers, total	78.19 ± 6.92	73.85 ± 6.19	152.04 ± 12.56	0.13 ± 0.02
Females	71.55 ± 6.78	75.89 ± 7.14	147.44 ± 13.54	0.12 ± 0.03
Males	86.25 ± 10.52	86.00 ± 9.20	160.14 ± 16.41	0.07 ± 0.01
Left-handers, total	74.27 ± 5.63	77.12 ± 5.68	151.12 ± 11.02	0.10 ± 0.02

Thus, on the basis of FA levels of fingerprint pattern distribution and the ridge count, at this stage of our research, we cannot say that left-handedness is associated with the destabilization of development.

In general, with respect to both the character of fingerprint patterns and the ridge count, women were observed to be highly similar to men, even in the features for which sexual dimorphism is usually observed, such as the ridge count and the delta index. The most significant findings are the differences in the distribution of radial arches between left-handed women and men; they do not reach a statistically significant level but are clearly evident. On the one hand, these facts can be explained by the small size of our samples, but, in our other studies, we also noted the absence of sexual dimorphism in the distribution of fingerprint patterns in Yakuts [75,76]. On the other hand, it should be taken into account that the Yakuts are genetically heterogeneous people, having invaded the modern territory of Yakutia in historically recent times, which pushed out the aboriginal tribes. There is evidence that Yakut men are characterized by a high genetical similarity, which indicates that their origin is from a relatively small number of founders. At the same time, Yakut women are characterized by greater genetic diversity, indicating that the founding women had different origins: some have the same as the men, and some are from the surrounding aboriginal tribes [69,77]. Perhaps it is this fact that is reflected in some of the dermatoglyphic features.

## 5. Conclusions

On the basis of test results using two sets of questions and tasks, dynamometry, and fingerprint examination of young Yakuts, we summarize our observations as follows.

According to the results of psychophysiological testing, the asymmetry coefficient in right-handers was +0.40 (dominance of the right hand), while in left-handers, it was −0.14 (dominance of the left hand). According to household and sports skills, it was +0.88 and −0.53, respectively. In the left-handed group, the spread of diagnostic features is statistically significantly higher than in right-handers. Among those who wrote with their right hand, only 1 in 40 subjects showed signs of ambidexterity. Among the left-handed writers, only 75% were diagnosed as left-handed, 17.5% showed signs of ambidexterity, and 7.5% had indicators of false right-handedness. Asymmetry in hand compression force in left-handers was less pronounced than in right-handers at a statistically significant level; among left-handed men, this difference was more pronounced than in women.

The analysis of fingerprints revealed no significant sex differences in the occurrence and distribution of fingerprint patterns in either left- or right-handed group. Comparison by handedness showed that left-handers were statistically significantly more likely than right-handers to have arch patterns, which were distributed symmetrically on both hands: if they were found on one hand, it was more likely to also be on the left. At the same time, in right-handers, arches were more often found on the right hand. Radial loops were most often observed on the index finger of either hand and, in left-handers, they had a significantly higher occurrence on three to five fingers of the left hand.

Left-handers, as compared with right-handers, had a significantly lower occurrence of whorls, so the delta index in left-handers was lower than that in right-handers: 1.24 and 1.40, respectively. The value of the summary ridge count was similar for right-handed and left-handed people: 152.0 and 151.4, respectively. There were no significant differences in the ridge count between the hands, but there was a trend noted: the ridge count in both groups was higher on the dominant hand. The ridge count in men tended to be higher than in women in both groups, but the differences did not reach a statistically significant level.

Fluctuating asymmetry was estimated by the distribution of fingerprint patterns, the average number of triradii, and the ridge count on the left and right hand. In neither right-handed nor left-handed people were there sex differences observed for these features. The average values of the asymmetric manifestation of patterns were 0.25 and 0.27 in left-handers and right-handers for the main types of patterns, and taking into account the pattern varieties, the values were 0.56 and 0.58, respectively. The values of fluctuating asymmetry in the ridge count in right-handers and left-handers were also similar:  $0.13 \pm 0.02$  and  $0.10 \pm 0.02$ .

Thus, at the group level, left-handed and right-handed people differed in the functional asymmetry of psychophysiological and motor reactions. Right-handed writers were characterized by a higher intragroup similarity, whereas a wide variation in the manifestation of features among the left-handed writers was observed. This suggests that the non-dominant hand of left-handers is subject to a relatively larger load, indicating the forced adaptation of left-handers to dextrastress. The diagnosis of left-handedness by testing with different methods and dynamometry at the group level presented positive correlations of moderate strength, with the most pronounced being the tasks for identifying the dominant eye and assessing general and sports skills. As for dermatoglyphic markers of left-handedness, we can point out an increase in the occurrence of arches and radial loops on the left hand, with a distribution of these features on more than two or three fingers per individual. Left-handed people showed no increase in fluctuating asymmetry of dermal patterns compared with the right-handed individuals.

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