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Finger Dermatoglyphics as Predictive Markers of Physical Abilities: Applications in Athlete Selection and Training

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Abstract

This article presents findings from over 13 years of research examining the association between finger dermatoglyphic traits - morphogenetic markers - and diverse manifestations of physical abilities in elite athletes, non-athletes, and individuals with congenital motor impairments. The study encompassed more than 2,000 subjects, including 1,559 athletes (ages 14-36) across 25 sports disciplines, 69 individuals with cerebral palsy (ages 2-40), 202 university students (ages 18-24), and 291 children and adolescents (ages 4-16). Dermatoglyphic parameters assessed included pattern type (arch, loop, whorl), ridge count, delta index (D10), total ridge count (TRC), and phenotypic formula. Results demonstrate that finger dermatoglyphic traits serve as markers for the preferential development of specific physical qualities, energy supply mechanisms of motor activity, and the risk of diminished physical potential. A systematic pattern was identified: D10, TRC, and whorl frequency increase progressively from cyclic speed-strength sports through cyclic endurance sports to acyclic coordination-dominant sports ($p < 0.05$ across all group comparisons). Arch-containing phenotypes (AL, ALW) were associated with reduced physical potential and predominantly creatine phosphate energy mechanisms, whereas loop-whorl phenotypes (LW, WL) predicted broader adaptive capacity with optimal performance under prolonged, high-coordination demands. The TRC/D10 ratio near 10 indicated normal regulatory balance, while deviations below 10 marked risk of diminished physical capacity. These findings were consistent across sex, with sport-specific modifications of sexual dimorphism reflecting the primacy of activity demands over biological sex in elite athlete selection. The dermatoglyphic phenotyping method is proposed as a rapid, non-invasive tool for early talent identification, sport-specific selection, playing position assignment, and individualization of training methods.

1. Introduction

Predicting human physical abilities is critically important for professional orientation and the identification of individuals whose genotype - comprising both rigidly heritable traits and adaptive range - is suited to specific types of activity (Kaznacheev & Kaznacheev, 1986; Zaitseva, 1994; Nikityuk, 1985). The need for validated criteria of physical abilities is especially acute in domains where professional success depends on extreme expression of particular physical qualities.

The relationship between professional demands and individual diversity in physical abilities is most clearly manifested in elite sport. Rational athletic selection and directed long-term training lead to the objective identification of individuals whose physical abilities are adequate for specific sport specializations. However, the extraordinary level of modern competitive results, which entails extreme functioning of all bodily systems, demands the earliest possible prognostic assessment of an athlete's physical potential in order to minimize material, physical, and psychological costs (Tanner, 1964; Kuznetsov, 1976; Martirosov, 2000; Suzdalnitsky & Levando, 1995, 2003).

At the stage of early orientation and initial selection, genetically informed criteria enable the identification, with high probability, of individuals possessing activity-appropriate heritable traits and adaptive range (Schwartz, 1974-1988; Nikityuk, 1978). The optimization of selection and individualization of training methods rests upon the search for valid criteria for the early diagnosis of definitive phenotypic manifestations as the result of genotype-environment interactions (Volkov, 1974; Bril, 1980; Balsevich, 2000).

Currently, the most developed criteria in sport are those largely determined by ontogenetic stage or current fitness level: physique, psychological status, physical qualities, rates of growth and biological maturation (Bakhrakh, 1966; Kuznetsov, 1976; Dorokhov, 1979; Timakova, 1983, 1988; Rodionov, 1983; Bulgakova, 1986; Martirosov et al., 1985). Contemporary investigations of genetic criteria for physical abilities have addressed skeletal muscle fiber composition, blood biochemical markers, the HLA complex, Q-heterochromatin, and angiotensin-converting enzyme (Gollnick et al., 1972; Saltin et al., 1977; Nekrasov & Shenkman, 1989; Gerard et al., 1986; Kurmanova, 1988; Asanov, 1986; Solovenchuk, 1989; Montgomery et al., 1999; Rogozkin & Nazarov, 2000). However, owing to insufficient development, invasiveness, and complexity of determination, these criteria have not achieved wide practical application.

In recent decades, dermatoglyphic traits have been widely investigated as markers of diverse phenotypic manifestations. Dermatoglyphic features are predominantly genetically determined, form between the 3rd and 5th month of gestation, remain unchanged throughout ontogeny, and exhibit high structural diversity and both individual and group variability (Gladkova, 1966; Guseva, 1986). Certain dermatoglyphic features provide highly reliable (90-95%) prognostic information for genetic disorders

and multiple developmental anomalies, as well as psychomotor and psycho-personal disturbances (Holt, 1968; Ritsner et al., 1971, 1972; Schaumann & Alter, 1976; Usoev, 1980; Guseva, 1986; Bogdanov, 1997).

Over 13 years, the Laboratory of Sports Anthropology, Morphology and Genetics at the All-Russian Research Institute of Physical Culture and Sports (VNIIFK) has studied finger dermatoglyphs as genetic markers associated with the predispositions underlying motor giftedness. A database has been compiled on finger dermatoglyphics in over 1,500 elite athletes across more than 20 sports, as well as in over 60 individuals (children and adults) with congenital motor impairments, and in non-athlete adults and youth at various developmental stages.

2. Finger Dermatoglyphs as Morphogenetic Markers

2.1. Fundamentals of Dermatoglyphics

Dermatoglyphics (from Greek *derma* - skin, *glyphe* - to engrave) is the science of skin relief patterns on palms and soles. The term was proposed by H. Cummins and C. Midlo and adopted at the 42nd annual session of the American Association of Anatomists in April 1926.

Finger dermatoglyphs (FD) are among the most studied and informative indicators of ridge skin (Cummins & Midlo, 1943; Schaumann & Alter, 1976; Mavalwala, 1978; Loesch, 1983). Individual variability in ridge patterns is extraordinarily high - the probability of identical patterns across all 10 fingers in different individuals is effectively zero. According to the Galton-Henry classification, which accounts for pattern shape and the number of triradii (deltas), three principal pattern types are distinguished:

- **Arches (A):** A delta-free open pattern, slightly convex distally, consisting of ridges crossing the finger pad transversely.
- **Loops (L):** A single-delta semi-closed pattern, open from either the ulnar (ulnar loop) or radial (radial loop) side; ridges begin from one edge, form a loop at the center, and return.
- **Whorls (W):** A double-delta closed pattern in which central lines are concentrically arranged around the pattern core; this type also includes double loops (S-patterns) and other complex forms with two or more deltas.

2.2. Pattern Distribution and Population Variation

According to world compilations (Chamla, 1963), arches are the rarest pattern type in most populations (0-7%); loops are most frequent among Caucasoids and Negroids (61-70% vs. 41-50% in Mongoloids); whorls predominate among Mongoloids (41-50% vs. 21-40% in other major races). Sexual dimorphism in FD is expressed as a higher frequency of complex patterns in males and simpler patterns in females (Gladkova, 1966, 1982).

2.3. Quantitative Parameters

The **delta index (D10)**, representing the total number of deltas across all ten fingers, is an independent dermatoglyphic trait that reflects integrated pattern complexity and serves as a racially, ethnically, and individually diagnostic indicator (Volotskoi, 1937; Gladkova, 1966; Khit & Dolinova, 1990). Maximum D10 is 20 (10 whorls); minimum is 0 (10 arches).

The **ridge count (RC)** is a quantitative measure of pattern size, assessed by the number of ridges along the line connecting the delta to the pattern center, excluding both the delta and central ridge (Galton, 1895; Bonnevie, 1924). Arch ridge count equals 0 due to the absence of a delta. The **total ridge count (TRC)** represents the sum of all local values.

2.4. Developmental and Genetic Basis

The formation of finger dermatoglyphics is completed during intrauterine development, coinciding temporally with the establishment of the leading regulatory systems - the nervous and endocrine systems - and occurring simultaneously with the differentiation of limb tissues from the ectodermal germ layer (Bonnevie, 1927, 1929; Nizimbetova, 1959; Samandari, 1973; Guseva, 1982; Carlson, 1983; Wertelecki, 1993). This co-development provides the basis for investigating associations between FD characteristics and diverse organismic manifestations.

FD represent a specialized tactile organ whose development is linked to limb tissue and organ development, including the nervous, endocrine, and circulatory systems, evolving in the process of establishing functional cerebral asymmetry. They are characterized by high individual diversity, immutability with age, and hereditary determination under the influence of sex - making them universal morphogenetic markers.

2.5. Dermatoglyphics in Clinical Medicine

Characteristic dermatoglyphic features have been identified in many hereditary diseases, supplementing diagnostic criteria and in some cases illuminating pathogenetic mechanisms. High frequencies of arch patterns and low TRC have been observed in triploidy, trisomy 8 mosaicism, tetrasomy 9, polysomy X, XXY and XYY syndromes, Rubinstein-Taybi, Patau, and Edwards syndromes (Holt, 1968; Guseva & Kazei, 1974, 1975; Schaumann & Alter, 1976; Solonichenko & Bogdanov et al., 1997). Epilepsy similarly shows a high proportion of arch patterns (Rosner et al., 1967; Pospišil et al., 1971; Kharitonov & Kozlova, 1985; Bogdanov, 1999).

Specific dermatoglyphic changes marking constitutional predisposition have also been noted in somatic diseases, including psoriasis (Gladkova & Lalaeva, 1972), peptic ulcer disease (Nikula et al., 1979), diabetes mellitus (Khamraeva & Khamraev, 1985), cardiovascular diseases (Akimova, 1989; Bitadze & Rudaeva, 1989; Tikhonov, 1990), and others.

2.6. Somatotype Correlations

Investigations have revealed associations between dermatoglyphic traits and body build parameters. The "arch-low ridge count" complex is associated with ecto-dolichomorphia and microsomia with decelerated development rates, while the "whorl-high ridge count" complex corresponds to brachymorphia and macrosomia with accelerated development rates (Boretsky, 1990; Kharlamov & Safonova, 2002; Trofimov, 1990; Nikityuk, 1978).

3. Finger Dermatoglyphs as Markers of Physical Abilities

3.1. Physical Abilities: Definition and Heritability

Physical abilities are hierarchically structured innate anatomical-physiological predispositions encompassing features of the central and peripheral nervous system, physiological and energetic characteristics, and body build (Zatsiorsky, 1979; Verkhoshansky, 1988; Matveev, 1991; Lyakh, 2000; Kryazhev, 2002).

All physical abilities show substantial heritability. The Holzinger heritability index (H) for key physical qualities ranges as follows:

Physical quality	Heritability (H)	Key references
Absolute muscular strength	0.37-0.87	Kovar, 1974; Sergienko, 1992
Reaction speed and complex quickness	0.60-0.87	Kovar, 1974; Sergienko, 1992
Aerobic capacity	0.80-0.90	Schwartz & Kramov, 1970; Klissouras, 1977
Anaerobic capacity	0.671-0.992	Gedda, 1960; Klissouras, 1977; Komi et al., 1977
Static endurance	0.621-0.754	Kovar, 1974; Savateeva, 1975
Coordination components (mean)	~0.55	Lyakh, 2000

Physical work capacity is inherited differentially for each physical quality (Sklad, 1975).

3.2. Study Design

To investigate associations between FD and physical abilities, populations with demonstrably different levels of physical capabilities were studied. In total, over 2,000 subjects were examined, including:

- 1,559 athletes (ages 14-36, various qualification levels, 25 sports);
- 69 individuals with cerebral palsy (ages 2-40);
- 202 university students (ages 18-24);
- 291 children and adolescents (ages 4-16) from Moscow and the Moscow region.

Methods included dermatoglyphic analysis, anthropometry, sport-specific fitness testing (strength, endurance, coordination), energetic capacity testing under incrementally increasing and competitive loads, and univariate and multivariate statistics (descriptive statistics, correlation, factor, and cluster

analyses).

FD phenotypes were classified as: AL (arches + loops), ALW (arches + loops + whorls), 10L (all loops), LW (loops + whorls, >5 loops), and WL (whorls + loops, >5 whorls).

3.3. FD and Sport Specialization

A systematic pattern was identified in elite male athletes across sport groups differing in biomechanics, dominant physical quality, and energy supply mechanisms:

Table 1. Principal FD traits in elite male athletes by sport group

Sport group	N	D10 (M, CV)	TRC (M, CV)	A (%)	L (%)	W (%)
Cyclic (speed-strength)	56	10.1, 18.4	98.1, 24.4	12.3	73.3	14.4
Cyclic (endurance)	255	12.7, 22.2	127.9, 21.5	4.2	65.7	30.0
Acyclic (endurance-coordination)	117	13.8, 15.3	140.6, 21.2	1.8	59.4	38.8
Acyclic (coordination)	149	14.3, 18.3	149.0, 19.1	0.8	50.9	48.3

D10, TRC, whorl frequency, and WL/LW phenotype prevalence increased progressively, while arch and loop frequencies and AL/ALW/10L phenotypes decreased systematically across the sport group continuum. All differences were statistically significant.

3.4. FD and Playing Position

In team sports, positional differences reflected the same directional pattern of FD variability:

Table 2. FD traits by playing position in team sports (elite athletes)

Sport / Position	n	D10 (M)	TRC (M)	Priority phenotype
Football				
Forwards	6	9.9	107.9	AL
Midfielders	9	14.1	154.8	LW, WL
Defenders	6	14.6	148.0	LW
Goalkeepers	3	16.3	162.3	WL, LW
Basketball				
Centers	6	10.5	110.8	10L, AL, ALW
Small forwards	8	13.0	130.9	LW, 10L
Guards	10	16.5	165.9	LW, WL
Volleyball				
Setters	3	11.3	140.0	10L, LW
Hitters	12	14.3	147.0	LW, WL

Increasing coordination demands with a shift from alactic-anaerobic to aerobic/glycolytic energy supply predisposed the selection of individuals with higher D10 and TRC and predominance of whorl patterns, while eliminating arch patterns.

3.5. Intra-Sport Specialization

Within-sport specificity followed the same pattern:

Table 3. FD traits by intra-sport specialization

Sport / Specialization	n	D10 (M)	TRC (M)	Priority phenotype
Speed skating				
Sprinters	22	9.9	95.7	AL, LW
All-rounders	37	14.4	147.6	WL, LW
Rowing				
"Motor" rowers	28	11.8	123.4	10L, LW
Stroke rowers	7	16.0	165.7	WL, LW

3.6. Sexual Dimorphism in Athletic FD

Comparison of male and female athletes revealed preserved but sport-modified sexual dimorphism. Overall, female athletes showed lower D10 (12.2 vs. 13.4) and TRC (116.8 vs. 141.6), with higher arch (6.8% vs. 2.4%) and loop (63.3% vs. 57.3%) frequencies, and lower whorl frequency (29.9% vs. 40.3%).

However, atypical sex differences were observed in cross-country skiing and road cycling, where female athletes showed *higher* whorl frequencies than males (43.0% vs. 23.0% in skiing; 48.3% vs. 26.8% in cycling). This correlated with the superior international competitive performance of Russian women relative to men in these disciplines, suggesting that the relationship between FD variability and sport-specific activity demands takes priority over biological sex in elite selection.

3.7. FD and Physical Qualities

Cluster and phenotypological analyses in elite rowers revealed differentiated "FD-physical quality" complexes:

Table 4. Relationship between FD classes and physical capabilities in elite rowers (cluster analysis)

FD class	D10	TRC	Minimum capability	Maximum capability
Class 1	5.5	27.5	Body size	-
Class 2	6.0	47.7	Speed-strength reserve	Strength, body size
Class 3	11.6	126.4	Endurance	Endurance, strength
Class 4	13.1	134.2	Strength	Coordination, endurance
Class 5	17.5	162.8	Coordination, endurance	-

Phenotypes with minimal D10/TRC and predominance of arches corresponded to low physical status. Loop predominance marked speed-strength predisposition. Integral complexification with complete arch elimination indicated innate priority of neuromuscular coordination. Intermediate values reflected general endurance predisposition.

3.8. FD and Bioenergetics

Sex-independent associations between FD phenotypes and energy supply characteristics were identified:

- **ALW phenotype**: Low energy capacity but high work power through efficient creatine phosphate and aerobic regulatory mechanisms.
- **LW phenotype**: High energy capacity at moderate work power with balanced aerobic and anaerobic regulation.
- **10L phenotype**: Predominant creatine phosphate mechanisms with sharply limited power and regulatory capacity under aerobic/anaerobic conditions.
- **WL phenotype**: High energy production (males) with dominant regulatory processes and optimal realization under creatine phosphate mechanisms.

3.9. FD and Congenital Motor Impairment

Investigation of individuals with cerebral palsy demonstrated a direct relationship between decreasing TRC/D10 ratio and severity of motor impairment:

Group	D10	TRC	TRC/D10
Controls	-	-	10
Partial impairments (Paralympic athletes)	-	-	8.1
Severe impairments (children)	-	-	7.0

Comparison of FD phenotype distributions between elite athletes and the general Russian population confirmed that arch phenotypes (AL, ALW) occurred 22% less frequently in athletes, while loop-whorl phenotypes (LW) occurred 19% more frequently - reflecting elimination of low-potential genotypes and selection for high-capacity genotypes.

4. Technological Aspects of Application

4.1. Step 1: Phenotype Assessment

The FD phenotype provides a holistic determination of the level and general direction of physical capability development:

- **AL, ALW phenotypes**: Reduced physical potential with maximal realization either in short-duration, high-power activity (creatine phosphate mechanism) or in prolonged, low-power activity (aerobic mechanism).
- **10L phenotype**: High realization in very short timeframes with declining capability under prolonged activity or complex motor patterns.
- **LW phenotype**: Broad adaptive capacity with stable regulatory reactions and wide adaptive range.
- **WL phenotype**: High-coordination optimization with tension in regulatory processes, manifesting as instability of neuromuscular and behavioral reactions under extreme conditions.

4.2. Step 2: Risk Factor Assessment

The TRC/D10 ratio evaluates the balance between pattern intensity and ridge count:

- **TRC/D10 ≈ 10**: Normal expression of phenotype-specific physical abilities.
- **TRC/D10 < 10**: Instability of regulatory mechanisms; risk of diminished performance under extreme conditions.

4.3. Sport-Specific Model Values

Table 5. Model FD values for elite athletes by sport group

Sport group	D10	TRC	Priority phenotypes
Cyclic speed-strength	< 11	< 110	AL, ALW, 10L
Cyclic endurance	10-13	111-130	LW
Acyclic endurance-coordination	12-15	120-150	LW, WL
Acyclic coordination-endurance	≥ 14	≥ 140	WL, LW

Table 6. Model FD values by Olympic sport

Sport	D10 range	TRC range	Priority phenotype
Speed skating (sprint)	9.0-10.8	86-106	AL, LW, 10L
Short track	9.9-10.7	92-105	ALW, LW, 10L
Sprint running	9.9-10.7	96-105	10L
Kayak	10.9-12.3	110-120	LW, 10L
Cross-country skiing	11.6-12.8	107-124	LW
Biathlon	12.1-13.2	123-139	All
Road cycling	12.0-13.2	133-145	LW
Rowing	12.0-13.3	130-148	All
Distance running	12.5-13.5	121-136	LW
Swimming	12.5-13.6	110-130	LW
Triathlon	12.6-13.8	120-140	LW
Nordic combined	12.7-13.9	129-147	LW, WL
Football	12.6-14.2	134-151	LW
Volleyball	13.0-14.4	136-154	LW, 10L
Freestyle skiing	12.4-14.6	125-142	LW, WL
Basketball	13.1-14.7	132-149	LW, 10L
Wrestling (freestyle)	13.7-14.6	159-172	LW, WL
Weightlifting	13.7-14.9	131-158	LW, WL
Speed skating (all-round)	13.9-14.9	141-156	WL, LW
Boxing	14.0-15.1	138-155	LW, WL

4.4. Position-Specific Model Values

Table 7. Model FD values by playing position

Sport / Position	D10	TRC	Priority phenotype
Football			
Forwards	9.5-10.1	97.6-116.2	AL
Midfielders	13.3-14.7	143.4-164.2	LW, WL
Defenders	13.5-14.9	137.8-156.2	LW
Goalkeepers	15.6-16.4	156.2-166.4	WL, LW
Basketball			
Centers	8.97-10.0	88.0-99.8	10L, AL, ALW
Small forwards	11.5-12.5	99.3-110.9	LW, 10L
Guards	14.4-15.6	127.8-148.8	LW, WL
Volleyball			
Setters	11.0-11.6	136.5-147.5	10L, LW
Hitters	13.8-14.8	142.8-151.2	LW, WL

5. Conclusions

The data presented provide an objective basis for implementing the dermatoglyphic method as a rapid diagnostic tool for assessing genetic potential in the following applications:

1. **Early sport orientation**: Identifying genotype-appropriate sport groups during early developmental stages, minimizing the material and physical costs of mismatched specialization.
1. **Comprehensive selection**: Serving as a "first calling card" of the athlete within the multi-criteria selection system, complementing anthropometric, functional, and performance-based assessments.
1. **Position assignment**: Providing evidence-based guidance for playing position selection in team sports (football, basketball, volleyball) and role function in technical sports (rowing, speed skating).
1. **Training individualization**: Identifying *a priori* dominant and limiting psychosomatic and functional properties, enabling targeted selection of training means and methods.
1. **Risk assessment**: Detecting individuals at risk for diminished physical potential through TRC/D10 ratio deviations and arch-dominant phenotypes.

It is important to emphasize that FD assessment does not carry dogmatic significance but rather defines the "corridor of psycho-functional capabilities" within which the individual's activity would be most successful and promising with minimal engagement of compensatory mechanisms. Conversely, FD assessment identifies domains where individual realization is limited and requires constant strain on the organism's protective resources. The method should be integrated with additional criteria (body build models, functional fitness, sport-specific performance) that characterize the particular demands of each competitive activity.

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