***Original Research Article***

**DERMATOGLYPHIC PATTERNS AND THEIR ASSOCIATION WITH MYOPIA AMONG SECONDARY SCHOOL STUDENTS IN SAGAMU, NIGERIA: A CROSS-SECTIONAL ANALYSIS**

**ABSTRACT**

**Aim**: Fingerprint patterns, influenced by both genetic and prenatal factors, serve as unique dermatoglyphic marker. Concurrently, myopia, a growing public health concern, disproportionately affects children and young adults. Recognizing parallels in the developmental pathways of dermal ridges and ocular structures, researchers have embarked on elucidating potential shared genetic or environmental networks. This study investigated the relationship between fingerprint patterns and myopia among secondary school students in Nigeria.

**Study Design:** Study sample consisted of 100 participants from the Junior Secondary student population of Integrity High School, Sagamu, Nigeria.

**Materials and methods**: Fingerprint data were collected using standard ink and paper methods, while myopia was identified utilizing the Snellen’s chart and refractive error lenses. Statistical analysis employed was Pearson chi-square correlation at a significance level of p < 0.05.

**Results**: Analysis revealed ulnar loop pattern as the most commonly found fingerprint pattern with 57% and 59% in male and female students respectively. However, chi-square correlation analysis unveiled noteworthy distinctions: myopic males exhibited a significantly higher prevalence of arch patterns in the right thumb (28.6%) compared to non-myopic counterparts (7%). Conversely, non-myopic males displayed a significantly higher occurrence of whorl patterns (23%) in both right and left hands compared to myopic peers (5.7%).

**Conclusions**: This study contributes to existing research affirming dermatoglyphics as morphological biomarkers, particularly in myopic males. Adding novel specificity of the right thumb as a distinctive marker. These findings underscore the potential utility of fingerprint analysis in identifying individuals at risk of myopia. Further investigation with larger sample is warranted to validate these preliminary results.

**Keywords**: Fingerprint patterns, Myopia, Arches, Right thumb.

**INTRODUCTION**

The assessment of cutaneous ridges and furrows present on the fingers, palm, sole, and toes is termed Dermatoglyphics, a Greek word meaning skin carving (Cummins & Midlo, 1926). Fingerprint patterns are unique epidermal ridges configurations on the volar aspect of digits (Cummins & Midlo, 1976). Fingerprint patterns are unique personalities of an individual such that no two fingers have the same fingerprints patterns and no two people have ever been found to have the same fingerprints (Prabha & Thenmozhi, 2014). Interestingly, it does not change from womb to tomb (Babler, 1991). It is used to establish the identity of individuals (Gutierrez-redomero *et al*., 2011). Additionally, personality and potential of a person can be determined based on the ten fingerprints (Offei *et al*., 2014).

Skins of the human fingers have some ridges which create special forms. This ridge formations begins to appear during the 6th to 7th week of embryonic development (Kücken & Newell, 2005). Dermatoglyphic pattern configurations are completed after the sixth prenatal month and will no longer change (Schaumann & Alter, 2012). During this crucial period dermal ridges may form in some abnormal patterns, thus they can be used in etiology of diseases (Cummins, 1926). This process is further influenced by genetic factors and environmental forces, with ridge configurations being genetically determined and influenced by the fetal volar pads (Swamynathan, 2013). Medical experts have confirmed that fingerprints provide accurate analysis of a person's multiple intelligences and also reflect one's genetic potential (Kumari *et al*., 2014). Furthermore, fingerprint patterns have also been established to be an indicator of chromosomal abnormalities and for diagnosis of some important diseases (Bhat *et al*., 2014). Dermatoglyphics have been confirmed to be related to various diseases, such as; Diabetes (Nezhad & Shah, 2012), myocardial infarction (Jalali & Hajian, 2002), Schizophrenia (Salvador *et al*., 2023), Alzheimer (Weinreb,1985), intellectual Disability such as Down Syndrome, Autism Spectrum Disorder and Attention-Deficit Hyperactivity Disorder (Sariza *et al*., 2021). Additionally, correlation between fingerprint patterns and different blood groups have been established (Fayrouz *et al*., 2012; Rastogi & Pillai, 2010). Genetics play a significant role in determining the unique patterns of human fingerprints. Galton, (1892) was the first to propose a connection between the human prints and genetics in 19th century. This relationship is further supported by Slatis *et al*., (1976), who proposed genetic theory for the inheritance of fingerprint patterns, he suggested that the involvement of various genes causes deviations from the basic fingerprint pattern sequence. Furthermore, Voitenko *et al*., (1979) developed a polygenic threshold model of finger dermatoglyphics inheritance. Recently, the significant influence of genetics on the development and inheritance of human fingerprint patterns have been evaluated. Ho *et al*., (2015) highlight the role of genetic factors in influencing fingerprint type by identifying common genetic variants that influence fingerprint patterns. Furthermore, Li *et al*., (2022) specifically identified 18 loci associated with fingerprint types.

Eye development is a genetically determined process regulated by transcription factors and homeobox genes (Zagozewski *et al*., 2014). Alteration in this process is associated with myopia, a defect of vision in which far objects appear blur and near objects are seen clearly (Marshall, 2020). Myopia is inherited defect that results from combined and interacting effects of hereditary and environmental factors. (King, 2017). Myopia, or nearsightedness, is a major public health issue, with a global increase in prevalence (Bremond-Gignac, 2020), particularly among children and young adults, due to increased digital screen use (Subudhi & Agarwal, 2022). More severe myopia known as high myopia, leads to severe vision related complications and a significant cause of social blindness, especially in East Asian countries (Ikuno, 2017). Genetic predisposition, prolonged near work, and lack of outdoor activities have been identified as risk factors for myopia (Marshall, 2020).

The etiology of myopia has been established to be related to certain ocular biometric parameters. Li *et al*., (2018) found that premyopic eyes have longer axial lengths and thinner lenses, indicating a potential link between biometric characteristics and development of myopia. Additionally, Xie *et al*., (2009), noted that myopia in young adults is linked to an increase in vitreous length and a decrease in para-foveal thickness. Furthermore, Fan *et al*., (2012), linked a genetic locus on chromosome 1q41, particularly the zinc-finger 11B pseudogene ZC3H11B, to ocular axial length and high myopia, suggesting a potential genetic basis for myopia. Malachkova *et al*., (2018) explored the role of TGF-β1 polymorphism in myopia, particularly in different degrees of myopia among European populations, concluding that increased scleral matrix remodeling can lead to exaggerated eye growth causing myopia.

The eye, crucial for vision, and the fingerprint, pivotal for individual identification, despite their disparate functions, their developmental trajectories exhibit striking parallels and share intriguing similarities. Both the eye and the epidermal ridges which give rise to fingerprints originate from ectodermal germ layer during early embryogenesis (Slack, 2021). Consequently, there are similarities in the intricate morphogenetic processes involving epithelial-mesenchymal **transition (EMT)**, that sculpt the final structures eye (Firsova, 2008) and fingerprints (Koster, 2004) during development.

Furthermore, the molecular signaling pathways governing the differentiation and patterning of the eye and the epidermal ridges also share intriguing similarities. Key signaling molecules such as; Sonic hedgehog (Shh) signaling, which is crucial for eye patterning (Swamynathan, 2013), also participates in the patterning of apical epidermal ridge (AER) (Laufer *et al*., 1994), which ultimately determine fingerprint patterns. Additionally, bone morphogenetic proteins (BMPs), fibroblast growth factors (FGFs) and Wnt proteins also play crucial role in the development both the eye and the epidermal ridges (Lopez-Pajares, 2013; Pincha, 2022). These connections suggest a potential link between fingerprint patterns and myopia, warrants. Thus, fingerprint analysis could be used in etiology eye defects and potentially serve as a non-invasive screening tool for identifying individuals at risk of developing myopia.

**MATERIAL AND METHODS**

Research sample comprised 100 Junior Secondary students of Integrity High School, Sagamu, Nigeria. They were selected according to sex and grouped into two: males (N=50) and females (N=50). Fingerprints were taken by standard ink and paper method described by Cummins & Midlo, (1976). Fingerprint patterns were classified according to Galton’s pattern classification; Arch, Composite, loops and whorls (Galton, 2004). They are differentiated according to landmark structures-triradius, a point from which three ridge systems course in three different directions at angles of about 1200, and a core point referring to the center of the pattern:

* Arches were the simplest pattern with no triradius, formed by succession of parallel ridges in which radiant flow in from one side and then out on the other side without making a return circle.
* Loops have one triradius and consist of series of ridges entering pattern area on one side, recurving and exiting from the same side. They are designated as radial, if the loop ridges open toward radius bone or thumb (RL), and ulnar, if the ridges open toward ulna bone or little finger (UL).
* Whorl patterns, with two triradii, have ridges arranged as circles, ellipses or spirals around the core of the pattern.
* Composite pattern, contains combination of two or more patterns either of same or different types in one print. The Core contains both in clockwise and anti-clockwise positions.

With the help of ophthalmologist with more than 20 years’ experience at Olabisi Onabanjo University Teaching Hospital Sagamu, Visual Acuity Assessment and Refraction Test were conducted to identify Myopic students. Snellen's chart was used to assess the clarity of vision at 20 feet distance for standard testing. refractive error lens was used to determine the extent of refractive error and confirm myopia diagnosis. Students with refractive error between -0.5 to -6.0 diopters(D) were diagnosed with common myopia (Maduka *et al*., 2009). Comparisons of patterns distribution between groups were made using chi-square test, with p value less than 0.05 considered as the minimum level of significance.

**Results**

Table 1 presents myopic status distribution of the participants; 13% of the whole population were diagnosed with common myopia (14% of males and 12% females).

Table 1: Myopic status distribution of the participants

|  |  |  |  |
| --- | --- | --- | --- |
| **MYOPIC STATUS** | **GENDER (%)** | | **TOTAL (%)** |
| **MALE** | **FEMALE** |
| **MYOPIC** | 7(14) | 6(12) | 13(13) |
| **NON-MYOPIC** | 43(86) | 44(88) | 87(87) |
| **TOTAL** | 50(100) | 50(100) | 100(100) |

Table 2 presents patterns distribution on participants Right Digits (RD1-RD5) and left Digits (LD1- LD5) in males. Ulnar loop pattern was the most common pattern. However, Comparison between myopic status revealed significant Increase of arch patterns in Right Hand first digit (Thumb) of Myopic male students and significantly increased Composite pattern in Nonmyopic male students.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **MYOPA** | | | | | **NONMYOPIA** | | | | | **PEARSON CHI-SQUARE** | |
|  | **ARCH**  **(%)** | **COMPO**  **(%)** | **RADIAL LOOP** | **ULNAR LOOP** | **WHORL**  **(%)** | **ARCH**  **(%)** | **COMPO**  **(%)** | **RADIAL LOOP** | **ULNAR LOOP** | **WHORL**  **(%)** | **P** | **X2** |
| **RD1** | 2(28.6) | 0(0) | 1(14.3) | 3(42.9) | 1(14.3) | 3(7.0) | 12(27.9) | 0(0) | 20(46.5) | 8(18.6S) | 0.027 | 10.98 |
| **RD2** | 2(28.6) | 0(0) | 1(14.3) | 4(57.1) | 0(0) | 5(11.6) | 4(9.3) | 2(4.7) | 16(37.2) | 16(37.2) | 0.198 | 6.02 |
| **RD3** | 1(14.3) | 0(0) | 0(0) | 6(85.7) | 0(0) | 4(9.3) | 1(2.3) | 0(0) | 26(60.5) | 12(27.9) | 0.413 | 2.86 |
| **RD4** | 1(14.3) | 1(14.3) | 0(0) | 2(28.6) | 3(42.9) | 0(0) | 4(9.3) | 0(0) | 21(48.8) | 18(41.9) | 0.077 | 6.83 |
| **RD5** | 1(14.3) | 0(0) | 0(0) | 6(85.7) | 0(0) | 1(2.3) | 2(4.7) | 0(0) | 33(76.7) | 7(16.3) | 0.298 | 3.68 |
| **LD1** | 3(42.9) | 0(0) | 0(0) | 4(57.1) | 0(0) | 3(7.0) | 5(11.6) | 2(4.7) | 29(67.4) | 4(9.3) | 0.080 | 8.34 |
| **LD2** | 2(28.6) | 1(14.3) | 0(0) | 4(57.1) | 0(0) | 5(11.6) | 2(4.7) | 7(16.3) | 19(44.2) | 10(23.3) | 0.272 | 5.15 |
| **LD3** | 1(14.3) | 1(14.3) | 0(0) | 5(71.4) | 0(0) | 4(9.3) | 2(4.7) | 2(4.7) | 28(65.1) | 7(16.3) | 0.630 | 2.58 |
| **LD4** | 2(28.6) | 1(14.3) | 0(0) | 4(57.1) | 0(0) | 5(11.6) | 8(18.6) | 0(0) | 19(44.2) | 11(25.6) | 0.347 | 3.30 |
| **LD5** | 1(14.3) | 1(14.3) | 0(0) | 5(71.4) | 0(0) | 2(4.7) | 3(7.0) | 1(2.3) | 31(72.1) | 6(14.0) | 0.649 | 2.47 |
| **TOTAL** | 16 | 5 | 2 | 43 | 4 | 32 | 43 | 14 | 242 | 99 |  |  |

Table 2: Patterns distribution on participants Right Digits (RD1-RD5) and left Digits (LD1- LD5) in males

Table 3 presents Patterns distribution on participants Right Digits (RD1-RD5) and left Digits (LD1- LD5) in females. Ulnar loop pattern was also the most common pattern. However, there was no significant dominant pattern in the right and left digits of both Myopic and nonmyopic male students.

Table 3: Patterns distribution on participants Right Digits (RD1-RD5) and left Digits (LD1- LD5) in females

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **MYOPA** | | | | | **NONMYOPIA** | | | | | **PEARSON CHI-SQUARE** | |
|  | **ARCH**  **(%)** | **COMPO**  **(%)** | **RADIAL LOOP** | **ULNAR LOOP** | **WHORL**  **(%)** | **ARCH**  **(%)** | **COMPO**  **(%)** | **RADIAL LOOP** | **ULNAR LOOP** | **WHORL**  **(%)** | **P** | **X2** |
| **RD1** | 1(16.7) | 0(0) | 0(0) | 3(50) | 2(33.3) | 5(11.4) | 6(13.6) | 0(0) | 18(40.9) | 15(34.1) | 0.790 | 1.04 |
| **RD2** | 1(16.7) | 0(0) | 0(0) | 4(66.7) | 1(16.7) | 5(11.4) | 4(9.1) | 3(6.8) | 20(45.5) | 12(27.3) | 0.772 | 1.80 |
| **RD3** | 1(16.7) | 0(0) | 0(0) | 5(83.3) | 0(0) | 4(9.1) | 0(0) | 2(4.5) | 32(72.7) | 6(13.6) | 0.688 | 1.47 |
| **RD4** | 0(0) | 1(16.7) | 0(0) | 5(83.3) | 0(0) | 2(4.5) | 2(4.5) | 3(6.8) | 24(54.5) | 13(29.5) | 0.342 | 4.50 |
| **RD5** | 0(0) | 0(0) | 0(0) | 6(100) | 0(0) | 3(6.8) | 0(0) | 3(6.8) | 35(79.5) | 3(6.8) | 0.683 | 1.49 |
| **LD1** | 1(16.7) | 2(33.3) | 0(0) | 3(50) | 0(0) | 5(11.4) | 2(4.5) | 4(9.1) | 19(43.2) | 14(31.8) | 0.080 | 8.10 |
| **LD2** | 2(33.3) | 0(0) | 1(16.7) | 2(33.3) | 1(16.7) | 8(18.2) | 0(0) | 3(6.8) | 20(45.5) | 13(29.5) | 0.629 | 1.73 |
| **LD3** | 1(16.7) | 0(0) | 0(0) | 5(83.3) | 0(0) | 7(15.9) | 0(0) | 2(4.65) | 23(52.3) | 12(27.3) | 0.420 | 2.82 |
| **LD4** | 0(0) | 0(0) | 0(0) | 5(83.3) | 1(16.7) | 3(6.8) | 5(11.4) | 1(2.0) | 25(56.8) | 10(22.7) | 0.748 | 1.93 |
| **LD5** | 0(0) | 0(0) | 0(0) | 5(83.3) | 1(16.7) | 1(2.3) | 1(2.3) | 2(4.5) | 37(84.1) | 3(6.8) | 0.880 | 1.18 |
| **TOTAL** | 7 | 3 | 1 | 43 | 6 | 43 | 20 | 23 | 253 | 101 |  |  |

Table 4 presents patterns distribution, both hands pooled together, in myopic and nonmyopic students from male and female group. Comparison within the same gender revealed significance dominant arch patterns in myopic males in relation to nonmyopic males. Conversely, there was high frequency of whorl in nonmyopic males. However, there was no significant dominant pattern type in both myopic and nonmyopic students of the female group (Table 4).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **PATTERN TYPE N (%)** | | | | | | |
| **GENGER** | **MYOPIC STATUS** | **ARCH** | **COMPOSITE** | **RADIAL LOOP** | **ULNAR LOOP** | **WHORL** | **P** | **X2** |
| **MALE** | **MYOPIA** | 16(22.9) | 5(7.1) | 2(2.9) | 43(61.4) | 4(5.7) | 0.00 | 24.47 |
| **NON-MYOPIA** | 32(7.4) | 43(10) | 14(3.3) | 242(56.3) | 99(23) |
| **TOTAL** | 48(9.6) | 48(9.6) | 16(3.2) | 285(57.0) | 103(20) |
| **FEMALE** | **MYOPIA** | 7(11.7) | 3(5.0) | 1(1.7) | 43(71.7) | 6(10) | 0.110 | 7.53 |
| **NON-MYOPIA** | 43(9.8) | 20(4.5) | 23(5.2) | 253(57.5) | 101(23) |
| **TOTAL** | 50(10) | 23(4.6) | 24(4.8) | 296(59.2) | 107(21.4) |

Table 4: Patterns distribution on both hands in males and females

**DISCUSSION**

The uniqueness of each person's ridge patterns has been utilized primarily by law enforcement officials for personal identification purposes (Kotzerke *et al*., 2016). However, broader medical interest in epidermal ridges has emerged upon discovering that individuals with chromosomal abnormalities often exhibit distinctive ridge formations (Cummins, 1926). Consequently, the examination of skin ridges offers a straightforward and cost-effective method to ascertain the presence of specific chromosomal defects in patients (Schaumann & Alter, 2012).

The utilization of dermatoglyphics as a diagnostic tool has become firmly established across various diseases with a strong hereditary component. This approach serves as a screening method for detecting anomalies and aids in predicting the diagnosis of genetic disorders (Bhat *et al*., 2014). Fingerprint patterns are considered dermatoglyphic markers, reflecting skin ridge development influenced by genes and prenatal stressors (Bhat *et al*., 2014). Padma (1980), suggest these markers might also indicate susceptibility to other developmental anomalies like myopia. Several hypotheses attempt to explain this potential link; both fingerprint patterns and eye development occur during critical stages of embryonic development and their developmental processes are similar (Schaumann & Alter, 2012). Sretić *et al*., (2019), propose that shared genetic or environmental factors influencing early development might affect both traits. This implies a potential shared regulatory network and possible genetic overlap. While genes likely play a role in both traits, identifying specific genes and understanding their interactions remains a challenge, Complex polygenic inheritance patterns and environmental factors further complicate the picture (Williams, 2017). However, the specific relationship between fingerprint patterns and myopia have not been directly addressed

Epidermal ridge patterns have been established as an etiological marker for ocular conditions. Padma (1980) found that retinal detachment patients had distinct dermal ridge configurations, with a significantly high frequency of whorls. These studies, although limited in scope, laid the groundwork for further investigation. Sretić (2018), observed significantly altered dermatoglyphic configuration of arch patterns in individuals with myopia compared to those with normal vision. Furthermore, (Sretić *et al*., 2019)has shown a potential association between fingerprint patterns and myopia, particularly in myopic males and confirmed altered dermatoglyphic configuration in myopic individuals. However, this study further contributes to this by discovering significant increased arch pattern in myopic males.

**CONCLUSION**

This study supports the hypothesis that dermatoglyphics is a morphological biomarker and plays a role in detecting diseases. This study discovered prevalence of arch pattern in right thumb as a diagnostic marker of myopia males, confirming Dermatoglyphics as a convenient tool to explain, compare and contrast, events. However, future investigations with larger sample and diverse populations of ethnicity and socioeconomic status would shed more light on both fingerprint formation and myopia development, potentially leading to improved diagnostic and preventive strategies.

**CONSENT**

As per international standards, parental written consent has been collected and preserved by the author(s). All the subjects willingly consented to participate actively in the exercise

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript

# REFERENCES

Babler, W. J. (1991). Embryologic development of epidermal ridges and their configurations. *Birth Defects Orig Artic Ser*, *27*(2), 95-112.

Bhat, G. M., Mukhdoomi, M. A., Shah, B. A., & Ittoo, M. S. (2014). Dermatoglyphics: in health and disease-a review. *Int J Res Med Sci*, *2*(1), 31-7.

Bremond-Gignac, D. (2020). [Myopia in children]. Medecine sciences: M/S, 36 8-9, 763-768.

Chandrasekaran, S., Chellammal, R., & Ganapathy, D. M. (2017). Dermatoglyphics: A tool in dentistry. *J Adv Pharm Edu*, *7*.

Cummins, H., & Midlo, C. 1976. Fingerprints, palms and soles. New York: Dover Publications Inc.,

Cummins, H. Epidermal ridge configurations in developmental defects, with particular reference to the ontogenetic factors which condition ridge direction. Am. I. Anat., 38:89, 1926.

Cummins, H., & Midlo, C. (1926). Palmar and plantar epidermal ridge configurations (dermatoglyphics) in European‐Americans. *American journal of physical anthropology*, 9(4), 471-502.

Fan, Q., Barathi, V.A., Cheng, C., Zhou, X., Meguro, A., Nakata, I., Khor, C.C., Goh, L., Li, Y., Lim, W., Ho, C.E., Hawthorne, F., Zheng, Y., Chua, D., Inoko, H., Yamashiro, K., Ohno-Matsui, K., Matsuo, K., Matsuda, F., Vithana, E.N., Seielstad, M., Mizuki, N., Beuerman, R.W., Tai, E.S., Yoshimura, N., Aung, T., Young, T.L., Wong, T.Y., Teo, Y.Y., Saw, S., & Wiggs, J.L. (2012). Genetic Variants on Chromosome 1q41 Influence Ocular Axial Length and High Myopia. PLoS Genetics, 8.

Fayrouz, I.N., Farida, N., & Irshad, A.H. (2012). Relation between fingerprints and different blood groups. Journal of forensic and legal medicine, 191, 18-21.

Firsova, N.V., & Zinovieva, R.D. (2008). Molecular genetic aspects of human eye development. Biology Bulletin, 35, 339-350.

Galton, F. 2004. Finger prints: The classic 1892 Treatise. New York: Dover Publications Inc.

Galton, F. (1892). Finger Prints (No. 57490-57492). Cosimo Classics.

Gutiérrez-Redomero, E., Alonso-Rodríguez, C., Hernández-Hurtado, L. E., & Rodríguez-Villalba, J. L. (2011). Distribution of the minutiae in the fingerprints of a sample of the Spanish population. *Forensic science international*, *208*(1-3), 79-90.

Ho, Y.Y., Evans, D.M., Montgomery, G.W., Henders, A.K., Kemp, J.P., Timpson, N.J., St Pourcain, B., Heath, A.C., Madden, P.A., Loesch, D.Z., McNevin, D., Daniel, R., Davey-Smith, G., Martin, N.G., & Medland, S.E. (2015). Genetic variant influence on whorls in fingerprint patterns. The Journal of investigative dermatology, 136, 859 - 862.

Ikuno, Y. (2017). OVERVIEW OF THE COMPLICATIONS OF HIGH MYOPIA. Retina, 37, 2347–2351.

Jalali, F., & HAJIAN, T. K. (2002). A comparative study of dermatoglyphic patterns in patients with myocardial infarction and control group.

King, D. (2017). Monochromatic aberrations, myopia, and emmetropisation. Other Conferences.

Kotzerke, J., Hao, H., Davis, S.A., Hayes, R., Spreeuwers, L.J., Veldhuis, R.N., & Horadam, K.J. (2016). Identification performance of evidential value estimation for ridge-based biometrics. EURASIP Journal on Information Security, 2016, 1-10.

Koster, M.I., & Roop, D.R. (2004). Genetic pathways required for epidermal morphogenesis. European journal of cell biology, 83 11-12, 625-9.

Kücken, M., & Newell, A. C. (2005). Fingerprint formation. *Journal of theoretical biology*, *235*(1), 71-83.

Kumari, D., Vijaya, B.D., & Kumar, D. (2014). Dermatoglyphics and its Relation to Intelligence Levels of Young Students. IOSRJDMS,13(5),01- 03. http://dx.doi.org/10.9790/085313520103.

Laufer, E., Nelson, C.E., Johnson, R., Morgan, B.A., & Tabin, C.J. (1994). Sonic hedgehog and Fgf-4 act through a signaling cascade and feedback loop to integrate growth and patterning of the developing limb bud. Cell, 79, 993-1003.

Li, L., Zhong, H., Li, J., Li, C., & Pan, C. (2018). Incidence of myopia and biometric characteristics of premyopic eyes among Chinese children and adolescents. BMC Ophthalmology, 18.

Li, J., Glover, J.D., Zhang, H., Peng, M., Tan, J., Mallick, C.B., Hou, D., Yang, Y., Wu, S., Liu, Y., Peng, Q., Zheng, S.C., Crosse, E.I., Medvinsky, A., Anderson, R.A., Brown, H.E., Yuan, Z., Zhou, S., Xu, Y., Kemp, J.P., Ho, Y.Y., Loesch, D.Z., Wang, L., Li, Y., Tang, S., Wu, X., Walters, R.G., Lin, K., Meng, R., Lv, J., Chernus, J.M., Neiswanger, K., Feingold, E., Evans, D.M., Medland, S.E., Martin, N.G., Weinberg, S.M., Marazita, M.L., Chen, G., Chen, Z., Zhou, Y., Cheeseman, M., Wang, L., Jin, L., Headon, D.J., & Wang, S. (2022). Limb development genes underlie variation in human fingerprint patterns. Cell, 185, 95 - 112.e18.

Lopez-Pajares, V., Yan, K., Zarnegar, B.J., Jameson, K.L., & Khavari, P.A. (2013). Genetic pathways in disorders of epidermal differentiation. Trends in genetics: TIG, 29 1, 31-40.

Maduka, F. C. O., Okoye, O. I., & Eze, B. I. (2009). Myopia: a review of literature. *Nigerian Journal of Medicine*, *18*(2).

Malachkova, N.V., Yatsenko, D.A., Ljudkevich, G., & Shkarupa, V.M. (2018). Polymorphism of TGF-β1 (rs1800469) in children with different degrees of myopia. Oftalmologicheskii Zhurnal.

Marshall, L. (2020). Myopia. Nature Reviews Disease Primers, 6, 1.

Nezhad, H. R., & Shah, N. M. (2010). Application of dermatoglyphic traits for diagnosis of diabetic type 1 patients. *International Journal of Environmental Science and Development*, *1*(1), 36.

Offei, E. B., Abledu, J. K., Osabutey, C. K., & Kesse, D. K. (2014). Relationship between palmar dermatoglyphic pattern and academic performance of students in a Ghanaian secondary school. *Journal of Medical and Biomedical Sciences*, *3*(2), 24-31.

Padma, T., Murty, J. S., & Satapathy, M. (1980). Dermal ridge configurations in retinal detachment. *Acta anthropogenetica*, *4*(1-2), 41–50.

Pincha, N., Marangoni, P., Haque, A., & Klein, O. D. (2022). Parallels in signaling between development and regeneration in ectodermal organs. In *Current topics in developmental biology* (Vol. 149, pp. 373-419). Academic Press.

Prabha, L. J., & Thenmozhi, R. (2014). A short review on dermatoglyphics. Journal of pharmaceutical sciences and research, 6(4), 200.

Priya, N. S., Sharada, P., Babu, N. C., & Girish, H. C. (2013). Dermatoglyphics in dentistry: An insight. World J Dent, 4(2), 144-147.

Rastogi, P., & Pillai, K.R. (2010). A study of fingerprints in relation to gender and blood group. Journal of Indian Academy of Forensic Medicine, 32, 11-14.

Sariza, A. A., Maristka, Z., Hayati, L., Inggarsih, R., & Purnamasari, S. (2021). Dermatoglyphics findings in intellectual disability children with down syndrome, autism spectrum disorder and attention-deficit hyperactivity disorder: A descriptive cross-sectional study. *Advances in Human Biology*, *11*(Suppl 1), S34-S39.

Salvador, R., García-León, M. Á., Feria-Raposo, I., Botillo-Martín, C., Martín-Lorenzo, C., Corte-Souto, C., ... & Pomarol-Clotet, E. (2023). Fingerprints as Predictors of Schizophrenia: A Deep Learning Study. *Schizophrenia Bulletin*, *49*(3), 738-745.

Schaumann, B., & Alter, M. (2012). *Dermatoglyphics in medical disorders*. Springer Science & Business Media.

Slack, J. M., & Dale, L. (2021). *Essential developmental biology*. John Wiley & Sons.

Slatis, H.M., Katznelson, M.B., & Bonné-Tamir, B. (1976). The inheritance of fingerprint patterns. American journal of human genetics, 28 3, 280-9.

Sretić, L., Labus, N., Filipović, T., & Filipović, M. (2019). Dermatoglyphics as a possible morphological biomarker in myopia: Analysis of finger ridge counts and fluctuating asymmetry. *Folia Morphologica*, *78*(2), 425–430. https://doi.org/10.5603/FM.a2018.0076

Sretić, L. (2018). Association between fingerprint patterns and myopia. *The University Thought - Publication in Natural Sciences*, *8*(2), 15–18. https://doi.org/10.5937/univtho8-18974

Subudhi, P., & Agarwal, P. (2022). Myopia. In *StatPearls [Internet]*. StatPearls Publishing.

Swamynathan, S. K. (2013). Ocular surface development and gene expression. *Journal of Ophthalmology*, *2013*.

Voitenko, V.P., Poliukhov, A.M., & Kolodchenko, V.P. (1979). [Inheritance of human fingerprints]. Genetika, 15 7, 1317-26.

Weinreb, H. J. (1985). Fingerprint patterns in Alzheimer's disease. *Archives of neurology*, *42*(1), 50-54.,

Williams, K. (2017). Cognitive, behavioural, environmental and genetic associations of myopia.

Xie, R., Zhou, X., Lu, F., Chen, M., Xue, A., Chen, S., & Qu, J. (2009). Correlation Between Myopia and Major Biometric Parameters of the Eye: A Retrospective Clinical Study. Optometry and Vision Science, 86, E503-E508.

Zagozewski, J.L., Zhang, Q., Eisenstat, D.D., & Eisenstat, D.D. (2014). Genetic regulation of vertebrate eye development. Clinical Genetics, 86.