


Comparative and Morphometric Study of Frictional Ridge Pattern of the Fingers and Toes Print of Clubfoot Patients in Akwa Ibom State, Nigeria

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Abstract

Background: Fingerprint is one of the most distinctive characteristics of the human body as each person's fingerprints are unique. **Objective:** This study was aimed at investigating the comparative and morphometric study of the friction ridge patterns of the fingers and toe prints of clubfoot patients in Akwa Ibom State, Nigeria. **Methods:** Fingerprints and toe prints from 40 clubfoot patients were collected for this study using the ink method. The different print patterns were analyzed and results were presented in frequencies and percentages. **Results:** Whorls appeared most frequently in both right and left hand (46.1%, 46.3%), ulna loop had (35%, 26.1%), Radial loop (12.2%, 17.8%), Arch (6.7%, 9.4%), plain Arch (2.2%, 2.2%), tented Arch (1.1%, 1.7%) and loop (0.6%) of fingerprint pattern. For the toe print pattern, whorls appeared most frequently on both right and left (36.7%, 46.1%), loop had (40.6%, 38.9%), Arch (21.7%, 15%), and plain Arch (1.1%). Chi-square analysis revealed significant differences in the ridge pattern of the fingers and toe prints of clubfoot patients. The right and left fingerprint patterns varied significantly amongst the fingers of clubfoot patients, while the right toe print pattern has no statistical association with toe print patterns of clubfoot patients, but the left toe print pattern varied significantly amongst the toes of clubfoot patients. Additionally, the morphometric analysis showed significant differences in the finger and toe ridge counts amongst various age groups in clubfoot patients. There was no statistically significant association of fingerprint ridge count amongst the various age

groups in clubfoot patients, while the toe print ridge count of both right and left toe varied significantly amongst the various age groups in clubfoot patients. The measurement of lower limb height in clubfoot patients has no significant comparison between both legs. **Conclusion:** The friction ridge patterns of the fingers and toes of clubfoot patients (CTEV) are unique and hence can be used for medical and forensic purposes.

Keywords

Morphometry, Fingerprints, Toe Prints, Clubfoot, Medical Forensic

1. Introduction

Each person's fingerprints are unique, which is why they have long been used for identification in forensic science. Surprisingly little is known about the factors that influence a person's fingerprint patterns. Like many other complex traits, studies suggest that both genetic and environmental factors play a role [1], hence a person's fingerprints are based on the patterns of skin ridges (called dermatoglyph) on the pads of the fingers [2]. These ridges are also present on the toes, the palms of the hands, and the soles of the feet. Although the basic patterns such as whorl, Arch, and loop may be similar, the details of the patterns are specific to each individual. Dermatoglyphs develop before birth and remain the same throughout life [3]. The ridges begin to develop during the third month of fetal development, and they are fully formed by the sixth month. The function of these ridges is not entirely clear, but they likely increase sensitivity to touch. The basic size, shape, and spacing of dermatoglyph appear to be influenced by genetic factors. Studies suggest that multiple genes are involved, so the inheritance pattern is not straight forward. Genes that control the development of the various layers of skin, as well as the muscles, fat, and blood vessels underneath the skin, may all play a role in determining the pattern of ridges [4].

There are three major types of fingerprint:

1) The Arch: This is the rarest type of fingerprint, in fact, about 5% of the world's population have this fingerprint pattern. Its lack of cores, lines or deltas makes it unique. Within this pattern, two other sub-categories emerge.

- Plain Arch: Raised ridges characterize this pattern and they extend from one side of the finger to the other in a continuous fashion. The pattern makes up a mere 5% of the total population, making it the rarest type [5].
- Tented Arch: Similar to the plain Arch, the tented Arch also has raised ridges flowing in the same fashion. The distinct difference comes in the pitch of the raised ridge. The tented Arch has a sharper edge compared to the plain Arch, which forms a tent-like shape [5].

2) The Whorl: This fingerprint pattern makes up about 25 to 35 percent of the total population. Unlike the Arch pattern, whorls have a core and two deltas. It's only similar to the Arch in the sub-categories, it has two.

- Plain Whorl: A plain whorl will make a circular pattern that represents a swirl or a spiral. This circular pattern is unbroken and this revolution at the center is a result of at least a single ridge [5].
- Central Pocket Whorl: The central ridges in this pattern will curve more than once in order to form a smaller inner whorl [5].

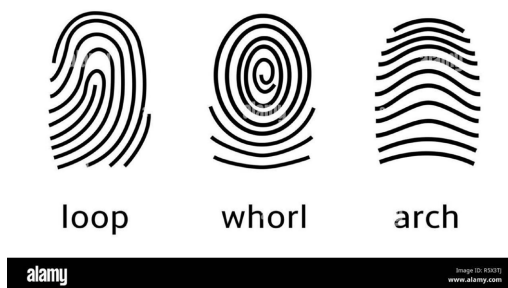
3) The Loop: This is the most popular fingerprint pattern with 60 to 70 percent of the total population having this pattern. In the loop pattern, there must be at least a single core and delta. The loop has three sub-categories.

- Ulnar Loop: In this pattern, the ridges turn backward, but they don't make a full turn.

To identify an ulnar loop, you'll notice the loops moving toward the small finger. You'll see these turns only if you view them on the hand and not on a card [5].

- Radial Loop: This pattern is similar to the ulnar loop, but the difference is the turns point toward the thumb instead of the small finger.
- Central Pocket Loop: The ridges in this pattern re-curve to surround the central whorl [5].

Apart from these three major types of fingerprints, two other types exist: Double Loop Whorl and Accidental.



Toe print is also a potential physiological characteristic of a person for the identification task. Toe print contains similar ridge patterns as the fingerprint impression as well as exhibits unique features (minutiae points) to differentiate the identity of an individual from another. In the past, the footprints have been used for verification of children [6]. The use case of footprint for grown-up children and adults is not feasible as the size limitation of acquisition sensors. Nevertheless, toe print can easily be acquired from standard fingerprint sensors, making toe print one of the possible biometric traits. The applications of toe print for biometric identification/verification can be significant for a person with different abilities. The area of toe print (big toe print) is larger than that of fingerprints, so it may contain more information (e.g. more minutiae points) as compared to the fingerprints. In addition, the foot of a person is generally covered; therefore, the possibility of leaving a toe print impression on any surface is negligible as compared to fingerprint, which makes this modality highly secure [7].

The following are the primary motivations for introducing toe print as a biometric trait:

1) Genetic defects: Adermatoglyphia [8] causes people to lose their fingerprints, and in some cases, they are not shaped properly (Hand Symbrachydactyly) [9].

2) Individuals lose fingers in automobile accidents, civil constructions, and at-home injuries. According to data, over 30,000 children and adults had their fingers amputated in doors and power tools.

3) In addition, the widely used fingerprint biometric system can be easily adapted to authenticate a user using toe prints. The authentication process does not necessitate the use of any additional hardware. In some countries, such as India (Aadhaar program), citizens are authenticated using biometric traits, and the most common of which is the fingerprint. Toe prints can serve as an option for those who do not have fingerprints [7].



A typical toeprint image source

Clubfoot, also known as Congenital Talipes Equinovarus, is a complex, congenital deformity of the foot if left untreated can limit a person's mobility by making it difficult and painful to walk [10]. It is defined as a deformity characterized by complex, mal-alignment of the foot involving soft and bony structures in the hind-foot, mid-foot and forefoot [11]. The deformity affects the structure and position of the foot, presenting as an adductus and cavus (an inward turning) of the mid-foot and a varus hind-foot. At the subtalar joint, the foot is held in a fixed equinus, or downward pointing position. The foot affected by clubfoot is shorter, and the calf circumference is less than a normal, unaffected foot [12]. On presentation, the clubfoot deformity is not passively correctable and presents with varying degrees of rigidity [13]. Clubfoot may be unilateral (30% - 40%) one or bilateral (60% - 70%). It is twice more common in males than females [14]. Clubfoot is the most common congenital malformation of the foot, affecting 1 - 2 newborns per 1000 [15]. Frequently, it is an isolated abnormality, but occasionally, it is associated with other congenital malformations or syndromes. Talipes Equinovarus comes from the following: "Tali" means Ankle, "Pes" means Foot, "Equinus" means foot pointing down (like a horse's foot), and "Varus" means deviated towards midline [16]. Clubfoot is of various types; positional clubfoot: This refers to a flexible foot that was held over time in an abnormal position in utero. When a child is born, due to the prolonged positioning, they may present with one or both feet in an atypical resting position. Children with positional clubfoot typically exhibit

unrestricted passive range of motion of forefoot and ankle [16]. The foot at the time of birth has some deformity, but bony alignment is not impacted and foot position is likely corrected through conservative treatment involving a program of stretching, range of motion and weight bearing.

Idiopathic Talipes equinovarus: This is most commonly also known as clubfoot; “Idiopathic” meaning there is no known cause for the deformity and is the most major type of clubfoot and is present at birth. This congenital anomaly is seen in 1 out of every 1000 babies with half of the cases of clubfoot involving one foot [16].

Neurogenic clubfoot: This type of clubfoot is caused by an underlying neurogenic condition such as spinal bifida, a clubfoot may also develop later in childhood due to cerebral palsy or a spinal cord compression [16].

Syndromic clubfoot: This type of clubfoot is found along with a number of other clinical conditions, which relate to an underlying clinical syndrome, such syndromes where a clubfoot can occur include diastrophic dwarfism, tibial hemimelia and constriction band syndrome [16].

It is estimated that 80% of cases of clubfoot occur in low- and middle-income countries [17]. Insufficient resources and medical services in these countries mean that there are high levels of disability from potentially treatable congenital anomalies such as clubfoot [18]. Many children born with clubfoot in low- and middle-income countries do not receive any treatment [19]. Untreated, the clubfoot deformity progresses to become a “Neglected Clubfoot” as the child with clubfoot eventually begins to walk. Due to the position of the foot the child weight-bears through the lateral and dorsal side of the affected foot, where a large bursa and callous form. As the child continues to walk, the soft and bony tissues are stretched further and the deformity worsens, resulting in pain and reduced mobility [19]. The consequences of the clubfoot deformity can have a great impact on the life of an individual. In some countries, girls with clubfoot may be less likely to marry [20], in others, the deformity is viewed by sectors of society as being the result of a curse [21]. Lack of mobility is extremely disabling in environments with poor transport infrastructure and where agriculture is the main source of income [17].

Treatment of clubfoot in low- and middle-income countries is a challenge; large numbers of children and adults with neglected clubfoot observed by surgeons visiting low- and middle-income countries are indicative of the scale of the problem [17]. The current state of services for clubfoot in most low- and middle-income countries is not well documented. However, it has been reported that in some countries, the predominant treatment option being offered is the Kite Method, as in Brazil [22]. In others, such as Malawi, prior to 2007, there were almost no services for clubfoot and no unified, nationwide approach to clubfoot management. Lack of services and belief that clubfoot is due to fate or is not treatable also mean that parents often do not seek treatment for their children [23].

Clubfoot is more common in males, with a 2.5 to 2.8:1 Male:Female ratio [2]. Various incidences have been noted between countries and regions ranging from

1 - 1.50 per 1000 live births, rising up to 3 per 1000 live births [2]. Similarly, ethnic differences in occurrence have been reported with the lowest incidence (0.6%) among the Chinese Population, while the highest incidence (6.8%) in the Polynesian Region. The accumulative incidence is approximately 1 per 1000 live births among Caucasians [24]. Worldwide 80% of children born with clubfoot are in low- and middle-income countries. The causes of clubfoot are poorly understood [25]. There is almost certainly a genetic component and environmental factors, seasonal variation and in utero positioning have all been suggested as possible causal factors, but these have not been consistently demonstrated [25]. In some countries and cultures, there are different beliefs about what causes a child to be born with clubfoot. These include spiritual influences, spells, or curses often leading to mothers being blamed for the deformity. These ideas can cause the child with clubfoot to be excluded from the society; hence, it is important to explain to families that children with clubfoot are a valuable part of the community.

Clubfoot can also happen to grown-up persons due to accidents. If it happens at birth, it is called congenital clubfoot, which is the most common congenital malformation of the foot with an incidence of 1 per 1000 births. There are two main types of congenital clubfoot: idiopathic (80% of cases) and secondary clubfoot (20% of cases). The idiopathic congenital clubfoot is a multi-factorial condition that includes environmental, vascular, positional, and genetic factors. The underlying mechanism involves disruption of the muscles or connective tissue of the lower leg, leading to joint contracture.

There is no established facts and information on the variations of the frictional ridges and distribution of the primary friction ridges of the fingers and toes of club foot patients in Akwa Ibom State, Nigeria. This study, therefore, will evaluate the comparative variations in the fingerprints and toe prints of the people of Akwa Ibom State, Nigeria.

2. Materials and Methods

This research employed the census research approach where data was collected from all the subjects. Subjects were composed of 40 patients in Akwa Ibom State with clubfoot anomaly. The following materials were used for this study: magnifying glass, lipstick, plain white sheet of paper, masking tape, foam pad table, wash hand basin, water detergent, hand towel and baby diapers.

This study was conducted using University of Uyo Teaching Hospital (UUTH), Uyo, St Joseph Rehabilitation Center, Essien Udim.

Ethnic clearance

Ethnic clearance for this study was obtained from Health research committee with the NO AKHREC/28/1/23/128.

Inclusion criteria

- 1) Only clubfoot patients.
- 2) Patients from age 0 - 30 yrs.

Exclusive criteria

Those without history of clubfoot excluded.

Method of data collection

In this method, the data was collected by using a lip stick and white plain sheets of paper. This was done by rubbing the lip stick on the palm and foot of the patient and placing it on the white plain paper for their fingerprint and footprint sample. The parameters used were the age, sex, and finger index of the clubfoot patients.

Statistical analysis

Data sample of fingerprint and toe print of talipes equinovarus was collected, screened for completeness and corrected, coded and entered into IBM statistical package for social science (SPSS) version 26 software. Univariate analysis was done for all variables. The data was presented in the form of prose, frequency, table, cross tables, pie charts and bar charts.

3. Results

Table 1 shows the percentage frequencies of the fingerprint pattern of right hand of the clubfoot patient, whorl patterns was predominant with 42.2%, ulnar loop by 35%, Arch 6.7%, tented Arch 1.1% and loop 0.6%. Result showed that the right fingerprint pattern varied significantly ($p < 0.05$) amongst the fingerprints of clubfoot patient.

Table 2 shows the percentage frequencies of left fingerprint pattern in clubfoot patient, whorl pattern was predominant with 42.8%, ulnar loop 26.1%, Arch 9.4%, plain Arch 22%, tented Arch 1.7% and Radial loop 17.8%. The left fingerprint pattern varied significantly ($p < 0.05$) amongst the finger of clubfoot patients.

Table 3 shows the percentage frequencies of right toe print pattern in clubfoot patient, loop pattern was predominant with 40.6%, whorl with 36.7%, Arch 21.7%, plain Arch 1.1%. Results showed that there was no statistically significant association ($p = 0.71$) amongst the right toe print pattern of clubfoot patients.

Table 4 shows the left toe print patterns in clubfoot patient, whorl was predominant with 46%, loop with 38.9% and Arch 15%. Result showed that the left toeprint

Table 1. Investigation of right fingerprint pattern in clubfoot patient.

Pattern	I	II	III	IV	V	Total	χ^2 statistics	χ^2 p-value
Wh	27 (75)	19 (52.78)	14 (38.89)	9 (25.00)	7 (19.44)	76 (42.2%)	60.82	0.00
A	1 (2.78)	2 (5.56)	3 (8.33)	4 (11.11)	2 (5.56)	12 (6.7%)		
L	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	1 (0.6%)		
PA	2 (5.56)	2 (5.56)	0 (0.00)	0 (0.00)	0 (0.00)	4 (2.2%)		
UL	2 (5.56)	5 (13.89)	14 (38.89)	19 (52.78)	23 (63.89)	63 (35%)		
RL	4 (11.11)	7 (19.44)	5 (13.89)	2 (5.56)	4 (11.11)	22 (12.2%)		
TA	0 (0.00)	1 (2.78)	0 (0.00)	1 (2.78)	0 (0.00)	2 (1.1%)		
Total	36	36	36	36	36	180 (100%)		

Table 2. Investigation of left fingerprint pattern in clubfoot patient.

Pattern	I	II	III	IV	V	Total	χ^2 statistics	χ^2 p-value
Wh	22 (61.1)	19 (52.8)	17 (47.2)	15 (41.7)	4 (11.1)	77 (4.8%)	37.23	0.01
A	2 (5.6)	0 (0.0)	5 (13.9)	4 (11.1)	6 (16.7)	17 (9.4%)		
PA	1 (2.8)	2 (5.6)	1 (2.8)	0 (0.0)	0 (0.0)	4 (2.2%)		
UL	7 (19.4)	6 (16.7)	8 (22.2)	11 (30.6)	15 (41.7)	44 (26.1%)		
RL	4 (11.1)	9 (25.0)	5 (13.9)	5 (13.9)	9 (25.0)	33 (17.8%)		
TA	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.8)	2 (5.6)	3 (1.7%)		
Total	36	36	36	36	36	180 (100%)		

Table 3. Investigation of right toe print pattern in clubfoot patient.

Pattern	I	II	III	IV	V	Total	χ^2 statistics	χ^2 p-value
Wh	16 (44.4)	16 (44.4)	9 (25)	11 (30.6)	14 (38.9)	66 (36.7%)	8.88	0.71
A	5 (13.9)	8 (22.2)	10 (27.8)	9 (25)	7 (19.4)	39 (21.7%)		
L	14 (38.9)	12 (33.3)	17 (47.2)	16 (44.4)	14 (38.9)	73 (40.6%)		
PA	1 (2.8)	0 (0.0)	0 (0.0)	0 (0.0)	1 (2.8)	2 (1.1%)		
Total	36	36	36	36	36	180 (100%)		

Table 4. Investigation of left toe print pattern in clubfoot patient.

Pattern	I	II	III	IV	V	Total	χ^2 statistics	χ^2 p-value
Wh	27 (75)	22 (61.1)	16 (44.4)	10 (27.8)	8 (22.2)	83 (46.1%)	31.65	0.00
A	4 (11.1)	4 (11.1)	7 (19.4)	7 (19.4)	5 (13.9)	27 (15%)		
L	5 (13.9)	10 (27.8)	13 (36.1)	19 (52.8)	23 (63.9)	70 (38.9%)		
Total	36	36	36	36	36	180 (100%)		

pattern varied significantly ($p < 0.05$) amongst the toes of clubfoot patients.

Table 5 shows the fingerprint ridge count amongst various age groups in clubfoot patients. Results were presented as follows; age groups 0 - 1 yr with ridge count (20,932,177) on the right and left fingerprint; age 1 - 2 yrs (448,454) on the right and left; 2 - 3 yr (234,229) on the right and left; 4 - 5 yrs (411,404) on the right and left; 11 - 12 yrs (225,218) on the right and left; 14 - 15 yrs (115,120) on the right and left; 16 - 17 yrs (395,390) on the right and left; 18 - 19 yrs (638,663) on both; The results revealed a total right count of 4559 on the right fingerprint in clubfoot and 4655 on the left fingerprint in clubfoot patients.

There was no statistically significant association ($P = 0.98$) of fingerprint ridge count amongst the various age groups in clubfoot patient.

Table 6 shows the toe print ridge count amongst various age groups in clubfoot patients. Results were presented as follows; age groups 0 - 1 yr with ridge count (20,832,197) on the right and left toe print; age 1 - 2 yrs (445,464) on the right and

Table 5. Investigation of fingerprint ridge count amongst various age groups in clubfoot patients.

Age groups	Right finger	Left finger	χ^2 statistics	χ^2 p-value
0 - 1 yr	2093 (23)	2177 (23)	1.54	0.98
1 - 2 yr	448 (5)	454 (5)		
2 - 3 yr	234 (3)	229 (2)		
4 - 5 yr	411 (5)	404 (4)		
11 - 12 yr	225 (2)	218 (2)		
14 - 15 yr	115 (1)	120 (1)		
16 - 17 yr	395 (4)	390 (4)		
18 - 19 yr	638 (7)	663 (7)		
Total	4559	4655		

Table 6. Investigation of toe print ridge count amongst various age groups in clubfoot patients.

Age groups	Right toe	Left toe	χ^2 statistics	χ^2 p-value
0 - 1 yr	2211 (48)	2002 (41)	147.89	0.00
1 - 2 yr	567 (12)	548 (11)		
2 - 3 yr	294 (6)	441 (9)		
4 - 5 yr	292 (6)	297 (6)		
11 - 12 yr	100 (2)	292 (6)		
14 - 15 yr	153 (3)	130 (3)		
16 - 17 yr	439 (9)	436 (9)		
18 - 19 yr	569 (12)	721 (15)		
Total	4625	4867		

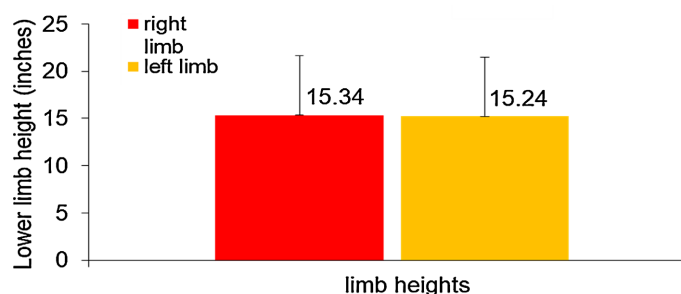
left; 2 - 3 yr (229,235) on the right and left; 4 - 5 yrs (411,404) on the right and left; 11 - 12 yrs (225,218) on the right and left; 14 - 15 yrs (115,120) on the right and left; 16 - 17 yrs (395,390) on the right and left; 18 - 19 yrs (638,663) on both; The results revealed a total right count of 4559 on the right toe print in clubfoot and 4655 on the left toe print in clubfoot patients.

There was no statistically significant association ($p = 0.98$) of toe print ridge count amongst the various age groups in clubfoot patient.

Information of lower limb height in clubfoot patients is shown in **Figure 1**.

4. Discussion

The science of dermatoglyphic is of interest in various fields such as medicine, clinical genetics, anthropology and criminology. Everyone possesses a unique set of fingerprints, toe prints and ridge patterns, Research has confirmed that these



Values are expressed as mean +SEM, n = 40.
* = significantly different from rightlimb at $p < 0.05$

Figure 1. Measurement of lower limb height in clubfoot patients.

patterns not only have a genetic significance, but that comparison of the finger and toe fingerprints and ridge patterns can reveal their genetic interdependence. In medicine, the ridge patterns have been linked to various medical condition whose genetic bases are not clear [26] and their utility in the prediction of congenital abnormalities and medical conditions such as hypertension and diabetes mellitus has been explored [27]. Findings of this study suggested that the fingerprints of clubfoot patients in Akwa Ibom State, Nigeria have abundant whorls followed by the loops pattern consisting of the radial and ulnar loops, while the tented and plane Arches were the least prevalent in both fingerprints. This result is different from the findings by [28] [29] who used the ink and lipstick methods to study the fingerprints patterns of the two major ethnic groups of Akwa Ibom State and documented the preponderance of loops followed by Arches than whorls in the major ethnic groups.

This research reports an equal number of plane Arches on both thumb and index finger of the right hand (5.56%) and index finger of the left hand, Arches on the index finger and thumb (5.56%) of the right and left hand, Ulnar loops (5.56%) and Radial loops (5.56%) on both thumb and middle finger of the right hand and tented Arches of the little finger of the left hand (5.56%). There was absence of tented Arches in the thumb and middle fingers of both right and left palm of the clubfoot patients. The highest frequency of ulnar loops was seen in the left and right little fingers of clubfoot patients, which is related to other findings that ulnar loops are the most prevalent irrespective of the population or ethnic group studied? Regarding the toe prints patterns, it was similarly observed a predominance of whorls followed by loops then Arches observed in both right and left foot of the clubfoot patients. The right and left first and second toe had the highest distribution of whorls (44.4%), (75%), (61.1%). The highest frequency of Arches in this study was noted on the right and left third toe (27.8%) and (19.4%) and this is in relation to findings by [30] who stated that there is a significantly higher frequency of Arches in the right toes than in the left toes. Akin to our findings, significant associations between clubfoot and the right toe print pattern was not established.

The right 3rd toe (47.2) and the left 4th toe (52.8) had the highest distribution of loops and a significant association was found in the left toe of clubfoot patients.

This study also showed a higher distribution of loops on the right toes, while the whorls and Arches were more common on the left toe, which is similar to findings by [31].

According to [31], dermatoglyphic areas of the hands and feet agree closely with the developmental sequence of an embryo and can therefore play a role in determining if finger and toe prints and ridge patterns have a role or can be used in the determination of congenital abnormalities such as clubfoot. The correlations are highest on homologous parts such as the fingers and toes. No significant association was found between the right and left finger ridge counts. The right and left limb heights were measured and a significant association was observed between the two limbs, thereby ascertaining that there is a relationship between the limb heights and clubfoot patients and this can be used to identify types and classes of clubfoot.

5. Conclusions

This study has clearly shown that the fingerprints of clubfoot patients do not follow the normal pattern of ulnar loops and Arches, but whorls and ulnar loops displayed by a combination of fingerprint patterns in all digits of a limb as against individual digits, while the toe prints of both limbs followed similar studies. Using correlation of mean ridge count, the ridge count of the left toe due to the significant relationship between them can be used to estimate the probability of descendants inheriting clubfoot and the limb height can also serve as possible pointers, hence results may be useful in genetics and anthropology.

The health sectors should have electrical finger and toe print scanning equipment that will be used for taking prints of clubfoot and other congenital abnormalities in patients at birth to enable and enhance more elaborate studies on finger and toe prints and their relationships to abnormalities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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