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Original Research Article

Hardy-Weinberg Equilibrium Study of Some Morphogenetic Traits in a Nigerian Population

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ABSTRACT

Background: The Hardy-Weinberg (HW) equilibrium studies the distribution of allelic and genotypic frequencies within a population. It provides a mathematical benchmark for a population that is evolving and not evolving.

Aim: This study investigated six morphogenetic traits among families in a Nigerian population using the Hardy-Weinberg principle with the aim of evaluating if the population was in HW equilibrium.

Methodology: A total of 45 families comprising a father, mother and at least one offspring were conveniently sampled in Ogbe- Ijoh district in Delta State, Nigeria. Earlobe attachment, Hand clasping, Hitchhiker's thumb, Leg folding, Morton's toe and Widow's peak were studied for their allelic and genotypic frequencies. The Chi-square test was used to analyse the association between these traits and sex, and conformance to the Mendelian inheritance pattern was evaluated with a Mendelian Chi-square. The Hardy-Weinberg equilibrium compared the allelic frequencies of parents with those of offspring.

Results: Males had higher frequencies for attached earlobes, Morton's toe and widow's peak (35.1, 51.9, 49.4%), while the females showed a predominance for hitchhiker's thumb, right hand clasping and leg folding (50,72.4,70.7%). There was no association between the traits and gender (p>0.05). From the Mendelian Chi-square, free earlobe, right-hand clasping, right leg folding, Morton's toe (SBt), the recessive phenotype of hitchhiker's thumb as well as widow's peak were the dominant traits **in the** studied population (**$X^2 < 3.841$**). The H-W equation revealed a deviation of the offspring's genotype from those of the parents for earlobe, hand clasping, leg folding, Morton's toe and widow's peak (1:1:2 [1:1; 4]; 2: 1: 3 [1:1:2]; 3:1:3 [1:1:2]; 5: 1: 4 [6:1:5}; 5:1:4 [7: 1:5]). However, parental and offspring alleles were identical for hitchhiker's thumb (5:1:5 [5:1: 5]). The homozygotes for both parents and offspring outnumbered the heterozygotes for all traits (295: 245; 156: 119).

Conclusion: The study showed that only the hitchhiker's thumb was in HW equilibrium, suggesting that evolution may not occur at that locus.

KEYWORDS: Hardy-Weinberg equilibrium, Mendel, Traits, Nigeria, Population.

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INTRODUCTION

A population is described as a set of organisms belonging to the same species, living simultaneously in a specific environment, influencing and mating with each other [1]. These individuals comprise a particular set of alleles, which are variants of occurring genes known as gene pools [1]. However, population genetics has been defined by several scholars as the study of the dissemination of genes and their alternative forms (alleles) within a population [2-3].

The Hardy- Weinberg (HW) principle states that in a large randomly mating population where there is no selection, mutation, or migration, the gene and genotype frequencies remain constant from one generation to another, and the population is declared as being in the Hardy- Weinberg equilibrium [4]. Shizong [4] further affirmed that the hypothesis of a large randomly mating population is an indication that there is no genetic drift and choice of mating. The HW equilibrium comprises an association between gene and genotype frequencies, coined in the square law [4]. Logically, the square law is represented by $(A_1+ A_2)^2 = A_1 A_1 + 2A_1 A_2 + A_2 A_2$. If p is taken as the frequency of the allele for A_1, then q=1-p becomes the allele frequency for A_2. In addition, p^2, q^2 and 2pq becomes the frequency of the genotype for $A_1 A_1$, $2A_1 A_2$ and $A_2 A_2$ respectively[4]. They represent the three basic combinations of alleles termed homozygous dominant, heterozygous dominant and homozygous recessive, which are expressed as phenotypes. This principle can estimate the occurrence of recessive alleles and carriers (heterozygotes) for several morphogenetic traits in a given population [4]. These traits are the sources of variation within a population [5]. Several include widow's peak, cheek dimples, earlobe morphology, Morton's toe, etc. [5-6].

Understanding human genetics creates an awareness of the variation of traits within a population, the source and mechanism of transmission of these variations, as well as tracing evolutionary history [7]. The first step in understanding traits in a given population is to study their occurrence and distribution within that population. The relevance of morphogenetic traits has been associated with the recognition of individuals, education of Mendelian principles and most recently, precise traits have been linked with the odds of definite human conditions [7]. There have been conflicting theories on the patterns of inheritance of some morphogenetic traits [7]. However, most of them have been studied on the assumption that they are monogenetic traits [7].

This study investigated six morphogenetic traits among families in a Nigerian population using the Hardy-Weinberg principle with the aim of evaluating if the population was in HW equilibrium. These traits will also be confirmed if they are monogenetic using the Mendelian Chi-square, suitable for teaching the principles of Mendelian genetics. The study was carried out due to a scarcity of information on population genetics among the Ijaw families residing in Ogbe-Ijoh, Delta State, Nigeria.

METHODS

The study was conducted in the Ogbe-Ijoh district, in Delta State, Nigeria, in 2023. The study comprised 45 families, comprising 45 fathers', 45 mothers' and 45 offspring. Participants were educated on the importance of the study and observed for the expression of these traits. The six qualitative traits (Earlobe attachment, Hand clasping, Hitchhiker's thumb, Leg folding, Morton's toe and Widow's peak) were studied for their allelic and genotypic frequencies within the population and confirming if the population was in HW equilibrium. Traits were assigned dominant and recessive using the Mendelian Chi-square [6]. The association between the expression of these traits and gender was done with the Chi-square test (*X^2*), with values less than 0.05 considered significant [7]. Analysis was done using the IBM SPSS Version 20 software (IBM Corp., Armonk, NY, USA) [7].

The Mendelian Chi-square determined if the traits were dominant or recessive on the hypothesis that they obey the rules of the dominant and recessive single gene Mendelian approach [6-8]. The data from the parents were pooled into three mating types (Traits present X Trait present; Trait Present X Trait Absent; Trait Absent X Trait Absent) according to published categorization [9]. The observed outcome from the offspring was then tested against the expected outcome from Mendelian principles corresponding to a Chi-square value of 3.841 at a 95% confidence level [6,8]. The HW principle was applied to calculate the frequencies of the alleles and genotypes of each trait within the studied population [6,8]. Ethical approval for this work was obtained from the Research and Ethics Committee, Department of Human Anatomy, Faculty of Basic Medical Sciences, Delta State University, Abraka, Nigeria (DELSU/ CHS /ANA/ 2023/81).

RESULTS

Table 1 shows the distribution of the morphogenetic traits in the studied population. A total of 33.3, 17.8, and 44.4% of fathers', mothers', and offspring had attached earlobes, while 66.7, 82.2 and 55.6% of them had free earlobes. The study also showed that a total of 46.7, 28.9, and 28.9% of fathers' mothers' and their offspring clasped their left hands on their right as compared to 53.3, 71.1, and 71.1% of them who clasped their right hands on their left.

Further findings showed that 51.1, 46.7, 48.9%, 48.9, 55.6, 48.9%, 48.9, 44.4, and 53.3% of fathers' mothers' and offspring had hitchhiker's thumb, Morton's toe and widow's peak. In addition, 46.7, 31.1 and 26.7% of fathers', mothers' and offspring folded their left legs on their right compared to 53.3, 68.9 and 73.3% of them who folded their right legs on their left.

Table 2 illustrates sex-associated differences among the six morphogenetic traits in the studied population. A total of 35.1 and 64.9% of males had attached and free earlobes, as compared to 27.6 and 72.4% of females. We also observed that 40.3% of males and 27.6% of females clasped their left hands on their right, while 59.7% of males and 72.45% of females clasped their right hands on their left. We only observed 48.1, 51.9, and 49.4% males, 51. 9, 50.0, and 48.3% of females with hitchhiker's thumb, Morton's toe and widow's peak. A total of 39.0% of males and 29.3% of females from this study folded their left legs on their right as compared to 61.0% of males and 70.70% of females who folded their right on their left legs. All morphogenetic traits in the studied population were without sexual preference ($p<0.05$).

The below table (Table 3) shows the data of the 45 families pooled, and the Mendelian Chi-square was used to compare the observed to the expected Mendelian outcome with the inference drawn from calculated results. We observed more insignificant with lower p values when the free earlobe was dominant over the attached earlobe; right-hand clasping was dominant over left, absence of hitchhiker's thumb was prevalent over its' presence, right folding of the leg was dominant over left folding, Morton's toe (SBt) was dominant over longer big toe (LBt), and absence of widow's peak was dominant over its presence. From this study, we can state from Mendelian calculations that free earlobe, right-hand clasping, right leg folding, Morton's toe and the recessive phenotype of hitchhiker's thumb along with widow's peak were the dominant traits in the studied population.

Table 4 shows the gene and genotypic frequencies of the six morphogenetic traits of the parents in the studied population. The Hardy-Weinberg equilibrium states that the genotypic frequencies, coined in the square law, must equal 1 ($p2+ q^2+2pq=1$) (4).

This is interpreted as homozygous dominant + homozygous recessive+ heterozygous dominant =1. The HW equilibrium is also centred on the constant allele frequencies over generations. This is termed $p+q=1$, where p is the dominant allele and q is the recessive allele. From the table above, the frequencies of the recessive alleles for earlobe attachment, hand clasping, hitchhiker's thumb, leg folding, Morton's toe, and widow's peak were 0.506, 0.606, 0.699, 0.624, 0.691 and 0.683 while those of the dominant alleles were 0.494, 0.394, 0.301, 0.376, 0.309 and 0.317 respectively.

The frequencies for homozygous recessive, homozygous dominant and heterozygous dominant for earlobe attachment, hand clasping, hitchhiker's thumb, leg folding, Morton's

Table 1: Distribution of Observed morphogenetic traits among Families in the studied population.

Observed morphogenetic traits	Family Member	Presented Patterns	Frequency (%)
Ear Lobe Attachment	Father	Attached	15 (33.3)
		Free	30 (66.7)
	Mother	Attached	8 (17.8)
		Free	37 (82.2)
	Offspring	Attached	20 (44.4)
		Free	25 (55.6)
Hand Clasping	Father	Left	21 (46.7)
		Right	24 (53.3)
	Mother	Left	13 (28.9)
		Right	32 (71.1)
	Offspring	Left	13 (28.9)
		Right	32(71.1)
Hitchhiker's Thumb	Father	Absent	22 (48.9)
		Present	23 (51.1)
	Mother	Absent	24 (53.3)
		Present	21 (46.7)
	Offspring	Absent	23 (51.1)
		Present	22 (48.9)
Leg Folding	Father	Left	21 (46.7)
		Right	24 (53.3)
	Mother	Left	14 (31.1)
		Right	31 (68.9)
	Offspring	Left	12 (26.7)
		Right	33 (73.3)
Morton's Toe	Father	Longer Big Toe	23 (51.1)
		Shorter Big Toe	22 (48.9)
	Mother	Longer Big Toe	20 (44.4)
		Shorter Big Toe	25 (55.6)
	Offspring	Longer Big Toe	23 (51.1)
		Shorter Big Toe	22 (48.9)
Widow's peak	Father	Absent	23 (51.1)
		Present	22 (48.9)
	Mother	Absent	25 (55.6)
		Present	20 (44.4)
	Offspring	Absent	21 (46.7)
		Present	24 (53.3)
		Total	135(100.0)

Table 2: Chi-square test of association of Observed morphogenetic traits among gender in the studied population.

Observed morphogenetic traits	Family Member	Presented Patterns	Frequency (%)	Chi-square	Df	P-value
Ear Lobe Attachment	Female	Attached	16 (27.6)	0.852	1	0.356
		Free	42 (72.4)			
	Male	Attached	27 (35.1)			
		Free	50 (64.9)			
Hand Clasping	Female	Left	16 (27.6)	2.341	1	0.126
		Right	42 (72.4)			
	Male	Left	31 (40.3)			
		Right	46 (59.7)			
Hitchhiker's Thumb	Female	Absent	29 (50.0)	0.05	1	0.823
		Present	29 (50.0)			
	Male	Absent	40 (51.9)			
		Present	37 (48.1)			
Leg Folding	Female	Left	17 (29.3)	1.358	1	0.244
		Right	41 (70.7)			
	Male	Left	30 (39.0)			
		Right	47 (61.0)			
Morton's Toe	Female	Longer Big Toe	29 (50.0)	0.05	1	0.823
		Shorter Big Toe	29 (50.0)			
	Male	Longer Big Toe	37 (48.1)			
		Shorter Big Toe	40 (51.9)			
Widow's peak	Female	Absent	30 (51.7)	0.015	1	0.902
		Present	28 (48.3)			
	Male	Absent	39 (50.6)			
		Present	38 (49.4)			
		Total	135(100.0)			

Table 3: Distribution of morphogenetic trait based on parental combination and offspring outcomes.

Traits	Parental combination	Total number of Offspring's			At : D		F : D	
		At (%)	F (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Ear Lobe Attachment	At in Both Pa	5 (100.0)	-	5(100.0)				
	EO (At : D)	5	-		1	**Not Sig**	2	**Not Sig**
	EO (F : D)	-	5					
	F in Both Pa	8 (29.6)	19 (70.4)	27 (100.0)				
	EO (At : D)	27	-		13.37	Sig	2.37	**Not Sig**
	EO (F : D)	-	27					
	At in Fa and F in Mo	4 (40.0)	6 (60.0)	10(100.0)				
	EO (At : D)	7.5	2.5		6.533	Sig	1.2	**Not Sig**
	EO (F : D)	2.5	7.5					
	F in Fa and At in Mo	3 (100.0)	-	3 (100.0)				
	EO (At : D)	2.25	0.75		1	**Not Sig**	9	Sig
	EO (F : D)	0.75	2.25					
	Parental combination	Total number of Offspring's			L : D		R : D	
		L (%)	R (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Hand Clasping	L in Both Pa	2 (33.33)	4 (66.67)	6(100.0)				
	EO (L : D)	6	-		1.667	**Not Sig**	1.333	**Not Sig**
	EO (R : D)	-	6					
	R in Both Pa	4 (23.5)	13 (76.5)	17(100.0)				
	EO (L : D)	17	-		9.941	Sig	0.941	**Not Sig**
	EO (R : D)	-	17					
	L in Fa and R in Mo	5 (33.33)	10 (66.67)	15(100.0)				
	EO (L : D)	11.25	3.75		13.889	Sig	0.556	**Not Sig**
	EO (R : D)	3.75	11.25					
	R in Fa and L in Mo	2 (28.56)	5 (71.44)	7 (100.0)				
	EO (L : D)	5.25	1.75		8.048	Sig	0.048	**Not Sig**
	EO (R : D)	1.75	5.25					
	Parental combination	Total number of Offspring's			P : D		A : D	
		Present (%)	Absent (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Hitchhiker's Thumb	P in Both Pa	10 (76.92)	3 (23.08)	13(100.0)				
	EO (P:D)	13	-		1.231	**Not Sig**	1.769	**Not Sig**
	EO (A:D)	-	13					
	A in Both Pa	3 (21.4)	11 (78.6)	14(100.0)				
	EO (P:D)	14	-		8.643	Sig	0.643	**Not Sig**
	EO (A:D)	-	14					
	P in Fa and A in Mo	6 (60.0)	4 (40.0)	10(100.0)				
	EO (P:D)	7.5	2.5		1.2	**Not Sig**	6.533	Sig
	EO (A:D)	2.5	7.5					
	A in Fa and P in Mo	3 (37.5)	5 (62.5)	8(100.0)				
	EO (P:D)	6	2		6	Sig	0.667	**Not Sig**
	EO (A:D)	2	6					
	Parental combination	Total number of Offspring's			L : D		R : D	
		Left (%)	Right (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Leg Folding	L in Both Pa	2 (33.33)	4 (66.67)	6(100.0)				
	EO (L : D)	6	-		1.667	**Not Sig**	1.333	**Not Sig**
	EO (R : D)	-	6					
	R in Both Pa	2 (12.5)	14 (87.5)	16(100.0)				
	EO (L : D)	16	-		12.25	Sig	0.25	**Not Sig**
	EO (R : D)	-	16					
	L in Fa and R in Mo	5 (33.3)	10 (66.7)	15 (100.0)				
	EO (L : D)	11.25	3.75		13.889	Sig	0.556	**Not Sig**
	EO (R : D)	3.75	11.25					
	R in Fa and L in Mo	3 (37.5)	5 (62.5)	8(100.0)				
	EO (L : D)	6	2		6	Sig	0.667	**Not Sig**
	EO (R : D)	2	6					
	Parental combination	Total number of Offspring's			Lt : D		St : D	
		Lt (%)	St (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Morton's Toe	Lt in Both Pa	10 (76.92)	3 (23.08)	13 (100.0)				
	EO (Lt : D)	13	-		1.231	**Not Sig**	1.769	**Not Sig**
	EO (St : D)	-	13					
	St in Both Pa	5 (33.3)	10 (66.67)	15 (100.0)				
	EO (Lt : D)	15	-		6.667	Sig	1.667	**Not Sig**
	EO (St : D)	-	15					
	Lt in Fa and St in Mo	6 (60.0)	4 (40.0)	10(100.0)				
	EO (Lt : D)	7.5	2.5		1.2	**Not Sig**	6.533	Sig
	EO (St : D)	2.5	7.5					
	St in Fa and Lt in Mo	2 (28.6)	5 (71.4)	7 (100.0)				
	EO (Lt : D)	5.25	1.75		8.048	Sig	0.048	**Not Sig**
	EO (St : D)	1.75	5.25					
	Parental combination	Total number of Offspring's			P : D		A : D	
		Present (%)	Absent (%)	Total (%)	Cal X^2	Infer	Cal X^2	Infer
Widow's Peak	P in Both Pa	10 (76.92)	3 (23.08)	13 (100.0)				
	EO (P:D)	13	-		1.231	**Not Sig**	1.769	**Not Sig**
	EO (A:D)	-	13					
	A in Both Pa	5 (33.3)	10 (66.67)	15 (100.0)				
	EO (P:D)	15	-		6.667	Sig	1.667	**Not Sig**
	EO (A:D)	-	15					
	P in Fa and A in Mo	6 (60.0)	4 (40.0)	10(100.0)				
	EO (P:D)	7.5	2.5		1.2	**Not Sig**	6.533	Sig
	EO (A:D)	2.5	7.5					
	A in Fa and P in Mo	2 (28.6)	5 (71.4)	7 (100.0)				
	EO (P:D)	5.25	1.75		8.048	Sig	0.048	**Not Sig**
	EO (A:D)	1.75	5.25					

*More Insignificant inference indicates similarity to the expected outcome proposed by Mendel.

* Calculated X^2 >= 3.841; Inference = Significant (Sig); Calculated X^2 < 3.841; Inference = Not significant (Not Sig)

Keys: At = Attached, F= Free, L= Left, R=Right, Lt= Longer Big toe, St= Shorter Big Toe, A= Absent, P=Present, Pa = Parents, Fa = Father, Mo= Mother, EO = Expected Outcome, At: D = If Attached is dominant, F: D= If Free is dominant, L: D= If Left is dominant, R: D= If Right is dominant, Lt: D= If Longer Big Toe is dominant, St: D= If Shorter Big Toe is dominant, A: D= If Absent is dominant, P: D= If Present is dominant, Sig = Significant, Not Sig = Not significant, Infer = Inference.

Table 4: Parental allele frequency distribution of observed morphogenetic traits in the studied population.

Morphogenetic Traits	Total Pop	q^2 (%)	Q	p^2 (%)	P	(2qp) (%)	Actual no of Homozy. Recessive	Actual no of Homozy. Dominant	Actual no of Heterozy. Dominant
Ear Lobe Attachment	90	0.256 (26)	0.506	0.244 (24)	0.494	0.500 (50)	23	22	45
Hand Clasping	90	0.367 (37)	0.606	0.156 (16)	0.394	0.478 (48)	33	14	43
Hitchhiker's Thumb	90	0.489 (49)	0.699	0.090 (9)	0.301	0.421 (42)	44	8	38
Leg Folding	90	0.389 (39)	0.624	0.142 (14)	0.376	0.469 (47)	35	13	42
Morton's Toe	90	0.478 (48)	0.691	0.100 (10)	0.309	0.427 (43)	43	9	38
Widow's peak	90	0.467 (47)	0.683	0.100 (10)	0.317	0.433 (43)	42	9	39

Table 5: Offspring allele frequency distribution of observed morphogenetic traits in the studied population.

Morphogenetic Traits	Total Pop	q^2 (%)	Q	p^2 (%)	P	2qp (%)	Actual no of Homozygous Recessive	Actual no of Homozygous Dominant	Actual no of Heterozygous Dominant
Ear Lobe Attachment	45	0.444(44)	0.667	0.111 (11)	0.333	0.444 (44)	20	5	20
Hand Clasping	45	0.289 (29)	0.537	0.214 (21)	0.463	0.497 (50)	13	10	22
Hitchhiker's Thumb	45	0.489 (49)	0.699	0.090 (9)	0.301	0.421 (42)	22	4	19
Leg Folding	45	0.267 (27)	0.516	0.234 (23)	0.484	0.499 (50)	17	11	22
Morton's Toe	45	0.511 (51)	0.715	0.081 (8)	0.285	0.408 (41)	23	4	18
Widow's peak	45	0.533 (53)	0.73	0.073 (7)	0.27	0.394 (39)	24	3	18

Table 6: Genotypic and phenotypic ratio of the studied morphogenetic traits for Parents and Offspring.

Morphogenetic Traits	Parents / Offspring (Genotypic ratio)	Parents / Offspring (Phenotypic ratio)
Ear Lobe Attachment	1:1:2 / 4:1:4	3:2 / 5:4
Hand Clasping	2:1:3 / 1:1:2	**1:1 / 1:1**
Hitchhiker's Thumb	**5:1:5 / 5:1:5**	**6:5 / 6:5**
Leg Folding	3:1:3 / 1:1:2	4:3 / 1:1
Morton's Toe	5:1:4 / 6:1:5	3:2 / 7:5
Widow's peak	5:1:4 / 7:1:5	3:2 /8:5

Note: Offspring inheritance patterns (conformance; black) and (outliners; red broken line) for the six morphogenetic traits

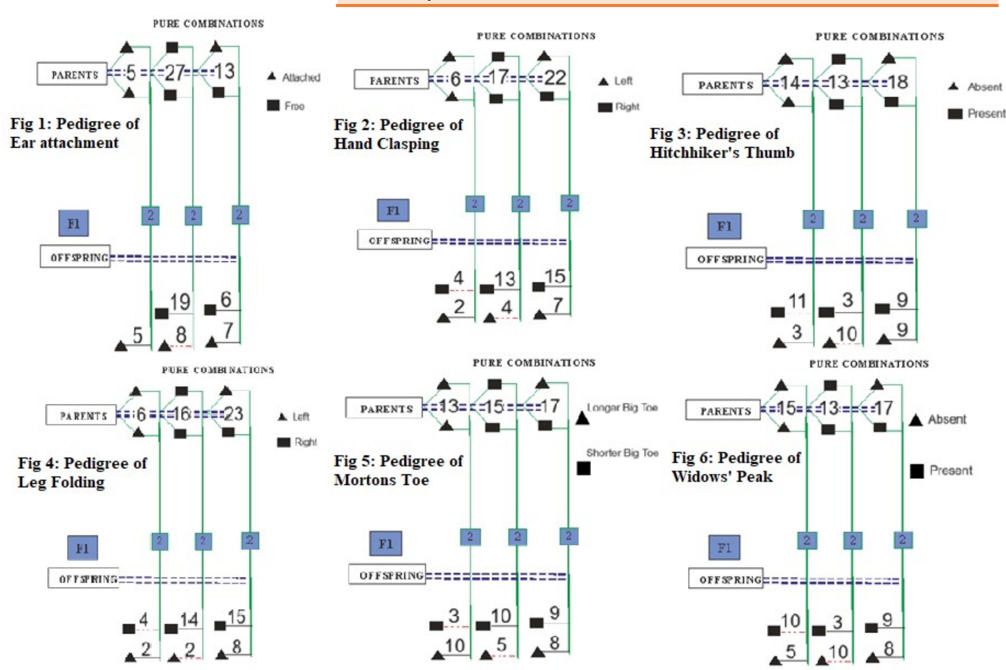

Fig 1-6: Pedigrees of the six morphogenetic traits amongst families in the studied population

toe and widow's peak were 0.444, 0.289, 0.489, 0.267, 0.511, 0.533; 0.111, 0.214, 0.909, 0.234, 0.081, 0.073; 0.444, 0.497, 0.421, 0.499, 0.408 and 0.394 respectively (Table 5).

Table 6 revealed that the parent's genotypic (**5:1:5 / 5:1:5)** and phenotypic (**6:5 / 6:5)** frequencies for hitchhiker's thumb were the same as those of the offspring.

DISCUSSION

Understanding the inheritance pattern can enable geneticists to foretell the likelihood of an offspring inheriting traits from either parent (10), which can be vital in settling parental controversy. The study showed that the free earlobe was dominant over the attached earlobe from the Mendelian calculated results. These findings were consistent with Asita *et al.* [7] and Ordu *et al.* [11]. They observed that the free earlobe was dominant over the attached from the Mendelian ratio.

This study also showed that this trait was without sexual preference, which does not fit into the assumption of a sex-linked or mitochondrial inheritance pattern. However, one of the assumptions of autosomal inheritance is that both males and females are always affected by the trait.

Morton's toe (SBt) from our study was dominant over the long big toe (LBt), suggesting that either parent may be homozygous dominant (MM) or heterozygous predominant (Mm), producing at least 25% offspring with the trait. Our findings were inconsistent with Aigbogun *et al.* [6], who noticed that the Longer big toe was dominant over Morton's toe from the Mendelian ratio. Nevertheless, our result was the same as that of Kaplan, who discovered that the length of the hallux was recessive compared to Morton's toe, which was dominant [12]. Differences could be a result of the genetic pool amongst the population. Morton's toe was also without sexual preference among families, which was tallied by Aigbogun *et al.* [6].

Mendelian statistics further showed that right-hand clasping and leg folding were dominant over left-hand clasping and leg folding without sexual differences. Lutze [13] did a survey on families for hand clasping and discovered a minor dominance of R offspring from the mating of R X R, as well as a slight dominance of L offspring from the mating of L X L. Lutze affirmed that hand clasping was genetically transferred from parents to offspring with no sexual differences. Still, he could not state the precise mode of inheritance. Several scholars also support Lutze's findings, affirming that hand clasping was genetically controlled [14-15]. A study by Reiss [16] on families observed that leg crossing was under genetic control.

Further findings suggest that the recessive phenotype for widow's peak and hitchhiker's thumb was the dominant trait, indicating that most parents were in the heterozygotes state for both traits.

All traits, except for the hitchhiker's thumb, were not in the HW equilibrium because there was a deviation of parental alleles from those of offspring in the studied population. The idea for utilising the H-W equation was to observe the allele distribution, if that of the offspring is consistent with the parental genotype [4]. There has been a long-standing postulation of Mendel that the genotype of the F1 generation is a representation of those of the parents expressing the dominance-recessive inheritance pattern, and a marked deviation from the parental combination is an indication that the alleles are not segregating in a fashion depicting Mendels' inheritance [4]. The equation to determine the contributing allele of a population helps in understanding the traits' conformance to a non-evolving population. When the genotypic and phenotypic ratio of the offspring and parents are remarkably different, it is an indication that the trait may be undergoing evolutionary change, and it negates the assumptions in Mendelian trait expression [4]. It should be noted that the emphasis on the need for genetic similarity between the parent and offspring is an ideological assumption that the combination of the parental allele and outcome in the offspring is not expected to be significantly different using the Mendelian chi-square. When this is observed, it simply illustrates that the offspring exhibits allele distributions that represent the parents' combinations to a great extent [4].

It is acknowledged that for a population to be in HW equilibrium, the population must be significant, there must be no mutations, there must be no migration in and out of the population (gene flow), mating must be random, and no natural selection must occur [4]. A deviation from these factors results in a population not being in the HW equilibrium. It is also affirmed that an evolutionary force is acting for a change of allelic frequencies.

The study also showed that males in the studied population had more attached earlobe, Morton's toe and widow's peak, while the females showed a predominance for hitchhiker's thumb, right-hand clasping and leg folding. Anibor et al. [17] studied the prevalence of attached earlobes among the Ika ethnic group, and John Nwolim Paul et al. [18] conducted a similar study on the Idoma people of Nigeria. They found that attached earlobes were more common in males. Aigbogun *et al.* [6] discovered that Morton's toe was predominant among Nigerians residing in Port Harcourt. However, Ebeye et al. [5] found that among the Esan people, widow's peak and attached earlobe are more prevalent in females than males, which contradicts our findings. John Nwolim Paul et al.'s investigation on hand clasping among Idoma people in Nigeria differed from ours. He observed that males were more right-hand claspers than females. Nevertheless, our findings were consistent with Onyije *et al*. [20], who observed a high proportion of females with hitchhiker's thumb in South Southern Nigeria. Differences could be due to ethnic variation.

CONCLUSION

The inheritance pattern of certain morphogenetic traits has been the subject of numerous debates. However, it cannot be definitively stated from a scientific perspective that these six traits follow a Mendelian pattern. Nonetheless, we have been able to determine which of the traits are dominant in the studied population by utilising Mendelian statistics.

Abbreviations

HW- Hardy-Weinberg
At - Attached,
F- Free, L- Left, R- Right, Lt- Longer Big toe,
St- Shorter Big Toe, A- Absent, P- Present,
Pa - Parents, Fa - Father, Mo - Mother,
EO - Expected Outcome, At:
D = If Attached is dominant,
F: D= If Free is dominant,
L: D= If Left is dominant,
R: D= If Right is dominant,
Lt: D= If Longer Big Toe is dominant,
St: D= If Shorter Big Toe is dominant,
A: D= If Absent is dominant,
P: D= If Present is dominant,
Sig = Significant, Not Sig = Not significant,
Infer = Inference.

Author Contributions

Lilian Ebele Chris-Ozoko: Concept and design of study

Jaiyeoba-Ojigho Jennifer Efe and Ubogu Joseph Aforkogene: Attainment of data

Emmanuel Ikechukwu Okolie: Analysis and elucidation of data

Jaiyeoba-Ojigho Jennifer Efe: Manuscript draft

Innocent Onyesom and Enaohwo Mamerhi Taniyohwo: Decisive correction of manuscript for vital scholar content

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