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Unveiling Genetic Equilibrium: A Study of Morphogenetic Traits in Benghazi, Libya

[1]Kamil S Mohamed, [2]Tarek M Shoeib, [3,]*Abdelmuhsen M. Abusneina and [4]Aebeed S. Aebeed

[1]Department of Zoology, Faculty of Sciences, University of Sirt, Sirt, Libya
[2]Department of Forensic Sciences, Faculty of Biomedical Sciences, University of Benghazi, Benghazi, Libya.
[3]Department of Molecular Diagnostics, Faculty of Biomedical Sciences, University of Benghazi, Benghazi, Libya.
[4]Department of Biology, Faculty of Education- Chemines branch, University of Benghazi, Libya

***Corresponding author:** Abdelmuhsen. Abusneina

Abstract

The morphogenetic traits, observable characteristics in the human body, are determined by one or more genes. These genes are inherited from parents to offspring in autosomal dominant or recessive modes. The shifts in gene frequencies within population gene pools can be analyzed through Hardy-Weinberg's law, providing insights into the foundation of diversity and variation across generations. The primary aim of this study is to investigate whether the gene pool of the Libyan population in Benghazi adheres to Hardy-Weinberg's law.

One hundred ninety-one families were randomly chosen from various regions in Benghazi city, encompassing 1061 individuals. The study used chi-square tests of independence to evaluate six morphogenetic traits. The frequencies of recessive traits were: Widow's peak Hairline (20.6%), Left-handedness (9%), Attached Earlobes (42.3%), Inability to fold tongue (38.5%), Cleft in chin (20.9%), and Hitch-hiker finger (39.7%). Gender distribution did not exhibit significant differences in these traits. However, the Libyan population in Benghazi did not show equilibrium according to Hardy-Weinberg's law. This discrepancy is attributed mainly to genetic drift and non-random mating, influencing the gene distribution within the population.

Keywords: Morphogenetic traits, Hardy-Weinberg equilibrium, population genetics, and Libyan population.

Introduction

In the intricate tapestry of the human body, genetic traits manifest visibly, governed by minute segments of DNA known as genes. Each gene harbours two alleles, one dominant and one recessive. Dominant alleles assert their effects irrespective the presence of a recessive allele, while recessive alleles only manifest their influence in the absence of a dominant counterpart. Through inheritance, offspring inherit alleles from both parents, resulting in combinations of homozygous or heterozygous traits. The interplay of these alleles orchestrates the development of specific characteristics observable in both progeny and progenitors [1, 2].

The stability of allele frequencies within a population across successive generations shows robust genetic variation, conferring resilience and longevity to the populace. Genetic diversity within human populations hinges upon the capacity of the gene pool; greater genotypic disparity increases genetic robustness, strengthening the population against diseases, environmental challenges, and other perturbations [3]. Conversely, diminished genetic diversity elevates the risk of population extinction [4].

Assessing the stability of allele frequencies and the adequacy of genetic variation within a population causes the application of Hardy-Weinberg's law. This principle posits that allele frequencies attain equilibrium in large, randomly mating populations devoid of migration,

mutation, or selection pressures. Deviations from this equilibrium signal the presence of factors such as small population size, non-random mating, migrations, mutations, or selection pressures, which impede genetic stability [2]. Given the lack of information regarding morphogenetic traits in the Libyan population, the present study investigates six morphogenetic traits and their respective frequency levels among the people of Benghazi.

Among these traits, tongue folding represents a unique physiological activity rather than a genetic aberration. A dominant allele governs the ability to fold the tongue inward, while the inability to do so is governed by a recessive allele [5]. A study was conducted in the Balochistan region of Pakistan, comprising 2,000 individuals, of which 1,153 were male and 847 were female. Their findings revealed that 63.55% of the sampled population could not fold their tongues, with 37.5% of females and 26% of males exhibiting this trait [6].

Similarly, the widow's peak hairline—a distinctive hairline formation resembling the letter 'V'—exhibits variability among individuals. While some possess a pronounced widow's peak, others have a straight hairline. Although multiple factors may influence the widow's peak, it is generally considered dominant over the straight hairline [7]. In Nigeria, a study on hairline shapes reported that 83.3% of the population exhibited a widow's peak, while only 13.7% had a straight hairline, potentially attributed to intermarriage within Nigerian populations [1]. Conversely, research conducted in Pakistan on 1,223 individuals found a higher prevalence of straight hairlines (64.75%) compared to widow's peaks (35.24%) [8].

It was shown that earlobes may exhibit attachment to the side of the head or remain unattached, delineating distinct phenotypic domains (Wiener, 1937). Attached earlobes are attributed to recessive traits governed by a specific gene with multiple alleles. Earlier studies by Carriere (1922) and Hilden (1922) suggested that attached earlobes were dictated by a dominant allele based on examinations of approximately 15 families. However, Whitney and Powell's investigation of a single family in 1937 affirmed that unattached earlobes were associated with a dominant allele [9]. Wiener further categorized earlobes into four distinct types, ranging from completely free (0) to wholly attached (3) [10].

A cleft chin, characterized by a slight hollow indentation in the center of the chin, due to incomplete bone fusion, is governed by a specific gene and is considered a dominant trait over a smooth chin [11]. In an early genetic inquiry into chin clefts within a single family, it was initially described as recessive but conceded the absence of conclusive evidence to support this assertion([12].

The ability to extend the thumb backward, known as the hitch-hiker's thumb, is controlled by a single gene. This trait, manifested by the capacity to lengthen the thumb, is attributed to a dominant allele, while the inability to straighten the thumb is linked to recessive traits. A previous study investigated the prevalence of hitch-hiker's thumb in South Nigeria, finding that 32.3% of the randomly selected 310 individuals possessed this trait, with 15.5% male [13].

Handedness, whether left or right-handed, emerges before birth and remains consistent throughout life, reflecting underlying differences in brain hemisphere function. Michel et al. (2016) noted that handedness likely arises from the developmental process of right-left asymmetry, with the right hemisphere controlling the left side of the body and vice versa [14].

Kohli and Sharma conducted a comprehensive study on 16 morphogenetic traits to determine their distribution and transmission patterns, particularly in India's Jammu, Himachal Pradesh, and Punjab regions. Their analysis revealed variations in trait frequencies, with some traits deviating from the expected Hardy-Weinberg equilibrium due to factors like mutations, non-random mating, and distribution effects [15]. Moreover, a previous study examined the impact of consanguinity marriages on the Libyan population in Benghazi, finding that approximately 40% of marriages exhibited non-random mating, indicative of specific societal influences on genetic transmission [16].

Materials and Methods

A community-based, descriptive, and cross-sectional approach was employed for this study. A survey encompassing 191 randomly selected families across various age groups involving 1,064 individuals was conducted. Six morphogenetic traits were assessed, as detailed in Table 1. The study was conducted in Benghazi city, in the northeast region of Libya (32°07′N 20°04′E/ 32.117°N 20.067°E) (Figure 01).

The investigation aimed to determine whether the population under study adheres to Hardy-Weinberg equilibrium. It was assessed using the chi-square test to determine any significant disparities between the expected gene frequencies and the observed frequencies across all morphogenetic traits within the population sample.

Figure 01. The geographical location of Benghazi.

Table 01. Morphogenetic Traits and Their Inheritance Patterns in this Study.

	Traits	Dominance	Recessive
1	Hair line	Widow's peak	Straight
2	Handedness	Right	Left
3	Earlobes	Free	Attached
4	Folding tongue	Ability	Inability
5	Cleft in chin	Cleft	Smooth
6	Hitch-hiker	Straight thumb	Hitch-hiker

Results

The analysis of morphogenetic traits among the studied population revealed intriguing patterns regarding various phenotypic characteristics. Hairline morphology showed that 20.6% of individuals exhibited a widow's peak, with 10.7% of males and 9.9% of females displaying this trait. Conversely, 41.0% of males and 38.4% of females had straight hairlines. Chi-square analysis revealed a significant association between gender and hairline type ($\chi2 = 10.75$, $p < 0.001$), with males exhibiting a higher prevalence of widow's peaks than females.

Handedness distribution revealed that the majority (91%) of the sampled population was right-handed, with 47.2% of males and 43.7% of females exhibiting this trait. Conversely, left-handedness was observed in 4.5% of both males and females. The chi-square test showed a highly significant association between gender and handedness ($\chi2 = 143.9$, $p < 0.001$), with right-handedness being predominant across genders.

Regarding chin morphology, 20.9% of individuals displayed a cleft chin, with 11.2% of males and 9.8% of females exhibiting this trait. The remaining 79.1% had a normal chin structure. The analysis revealed a significant association between gender and chin cleft presence ($\chi2 = 9.4$, $p = 0.002$), with males showing a slightly higher prevalence of cleft chins than females.

Earlobe morphology exhibited a predominance of free earlobes, observed in 57.7% of individuals, with 30.3% of males and 27.4% of females possessing unattached earlobes. Attached earlobes were observed in 42.3% of individuals, with 21.5% of males and 20.8% of females exhibiting this trait. The chi-square test showed a significant association between gender and earlobe attachment ($\chi2 = 169.72$, $p < 0.001$), with a slightly higher prevalence of attached earlobes among males.

Tongue folding ability was prevalent in 61.5% of individuals, with 32.9% of males and 28.7% of females capable of folding their tongues. Conversely, 38.5% of individuals could not fold their tongues. The chi-square test revealed a significant association between gender and tongue-folding ability ($\chi 2 = 102.43$, $p < 0.001$), with a slightly higher prevalence of tongue-folding ability among males.

Hitch-hiker's thumb prevalence was observed in 39.7% of individuals, with 20.5% of males and 19.2% of females possessing this trait. Straight thumbs were observed in 60.3% of individuals, with 31.2% of males and 29.0% of females exhibiting this characteristic. The chi-square test showed a significant association between gender and hitch-hiker's thumb presence ($\chi 2 = 121.94$, $p < 0.001$), with a slightly higher prevalence of hitch-hiker's thumbs among males.

Table 2. The distribution of morphogenetic traits frequency categorized by gender.

Traits		No. of Males (%)	No. of Females (%)	Total	HWE, Chi-Square - df= 1, CI = 95%		
					Asymp. Sig.	X^2 Calc.	Residual
1. Hair line	Widow's peak	114 (10.7%)	105 (9.9%)	219	0.001	10.75	46
	Straight	435 (41.0%)	407 (38.4%)	842			
2. Handedness	Left	48 (4.5%)	48 (4.5%)	96	0.000	143.9	169.3
	Right	501 (47.2%)	464 (43.7%)	965			
3. Cleft in chin	Cleft	117 (11.2%)	105 (9.8%)	222	0.002	9.4	43.3
	No cleft	432 (40.7%)	407 (38.3%)	839			
4. Earlobes	Attached	228 (21.5%)	221 (20.8%)	449	0.000	169.72	183.8
	Free	321 (30.3%)	291 (27.4%)	612			
5. Folding tongue	Inability	200 (18.8%)	208 (19.6%)	408	0.000	102.43	142.8
	Ability	349 (32.9%)	304 (28.7%)	653			
6. Hitch-hiker	Hitch-hacker	217 (20.5%)	204 (19.2%)	421	0.000	121.94	155.8
	Straight thumb	332 (31.2%)	308 (29.0%)	640			

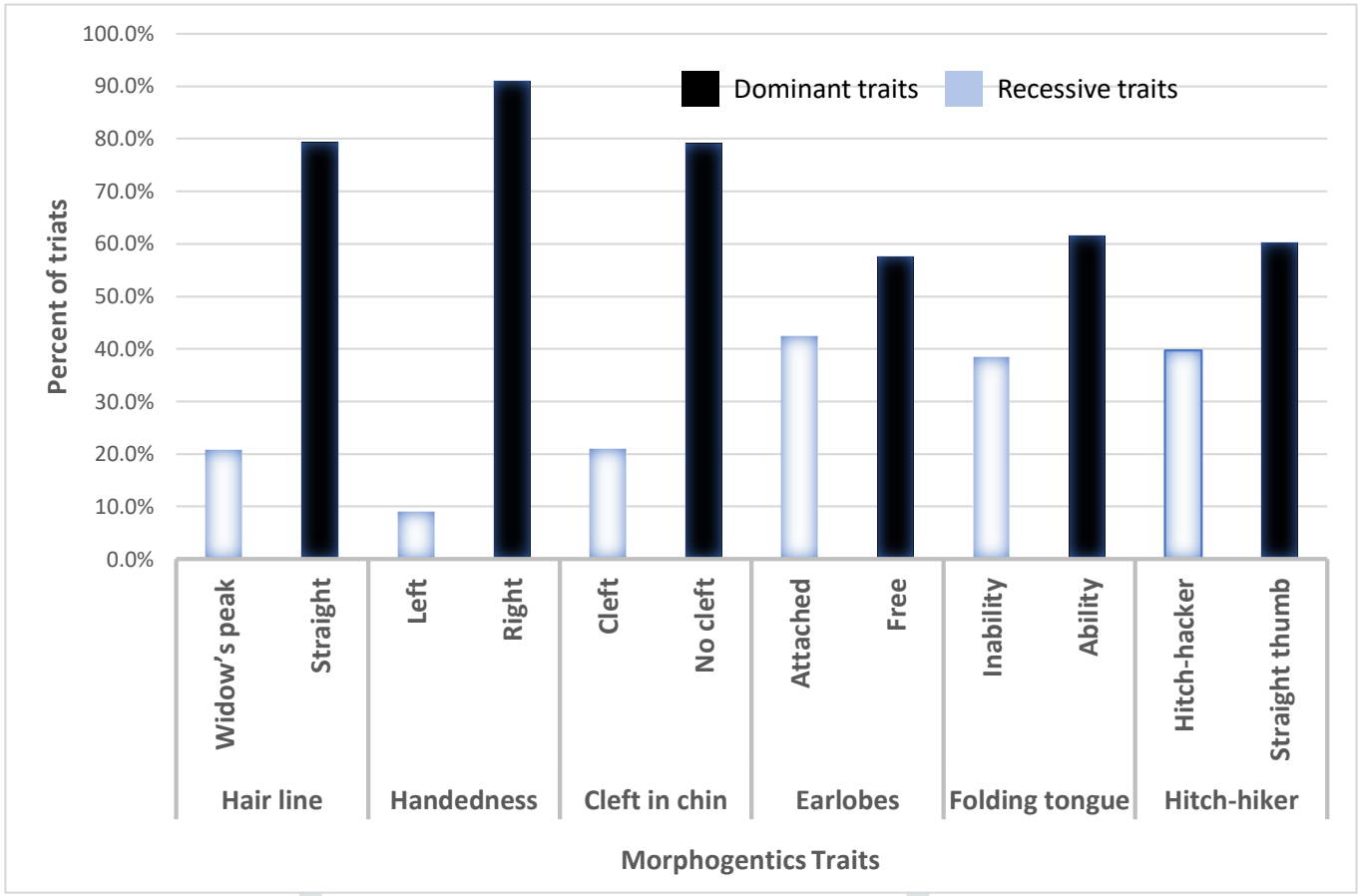

Figure 2. The percentage of dominant and recessive morphogenetic traits within the Libyan population.

Discussion

Our investigation into morphogenetic traits within the Libyan population yielded convincing insights, prompting a nuanced discussion of key findings. The identified traits were stratified into two partitions based on their prevalence, revealing intriguing patterns associated with the size of the Libyan population and consanguinity practices.

The first partition, encompassing traits like hair, handedness, and cleft in the chin, displayed a low percentage (below 25%) of recessive traits. This phenomenon was attributed to the small size of the Libyan population, invoking the influence of genetic drift [17]. In contrast, the second partition exhibited a higher prevalence of recessive traits (above 25%), primarily attributed to non-random mating or consanguinity in the Libyan population [16].

A critical chi-squared analysis of Hardy-Weinberg Equilibrium (HWE) shed light on the departure of allelic frequencies from the expected equilibrium. Notably, three recessive traits, attached earlobes, folding tongue, and hitch-hiker—surpassed the 30%. This deviation strongly indicated the existence of influential factors such as non-random mating and genetic drift in shaping the frequencies of these recessive traits within the Libyan population [16, 18, 19].

The examination of attached earlobe traits revealed a striking recessive allele frequency of 42.3%, with subtle variations observed between genders. Comparisons with a study on the Esan ethnic group in Nigeria underscored shared factors like isolation and genetic drift, contributing to similar trait frequencies in distinct populations [20].

The recessive traits of folding tongue and hitch-hiker exhibited notable frequencies of 38.5% and 39.7%, respectively, in the Libyan population. Comparative studies with a Pakistani sub-population showed a high prevalence (63.55%) of individuals unable to fold their tongue, associated with the prevalent practice of consanguineous marriages in Pakistan [21].

In Pakistan, research uncovered a higher occurrence of straight hairlines (64.75%) compared to widow's peaks (35.24%). When comparing results from Nigeria, the study also found divergence in frequencies, which underscores the regional genetic diversity in these morphogenetic traits (Ordu and Agi, 2014).

The study investigated the genetic landscape of handedness, challenging previous findings from England. While English research showed an 18% representation of left-handed individuals, our study suggested a higher prevalence of right-handedness, especially in parents and their offspring [22]. This contradicts the notion that handedness is not essentially genetic, as our findings align with a broader review of multiple studies supporting a hereditary influence on handedness [23-25].

Contrary to Hardy-Weinberg's law predicting constant gene frequencies across generations, our results showed a consistent gene frequency of 20.1% among total parents and 21.1% among their offspring. This suggests that forces like gene flow, sample size, or genetic drift continue to influence the population's genetic makeup [17].

Conclusion

The findings of this study provide valuable insights into the distribution of morphogenetic traits within the studied population of Benghazi, Libya. The prevalence of specific phenotypic characteristics, such as hairline type, handedness, chin morphology, earlobe attachment, tongue folding ability, and hitch-hiker's thumb, varied across genders, highlighting the influence of genetic and environmental factors on trait expression.

Notably, the observed frequencies of specific traits, such as widow's peak hairline and right-handedness, were consistent with established patterns in human populations. Conversely, the prevalence of other traits, including cleft chins and hitch-hiker's thumbs, exhibited variability, suggesting potential genetic heterogeneity or environmental influences within the population.

The significant associations between gender and morphogenetic traits underscore the importance of considering biological factors in understanding trait variability. Moreover, the deviation from Hardy-Weinberg equilibrium for certain traits suggests the potential influence of evolutionary forces, genetic drift, or non-random mating within the population.

Overall, these findings contribute to our understanding of the genetic diversity and phenotypic variation present in the Libyan population of Benghazi. Further research incorporating larger sample sizes and genetic analyses could explain the underlying mechanisms driving trait expression and inform future studies on human genetics and evolution.

Disclosure of conflict of interest:

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval:

This research study has been approved and conducted in accordance with the ethical principles outlined in the medical research ethics committee at the University of Sirt, Libya, and informed consent form was obtained from each individual participant in this study.

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