Journal of Life and Social Sciences
eISSN: 3006-2675
www.bbasrjlifess.com
*J. Life Soc. Sci, 2025; Volume, **4**: 42*

Original Research Article ***Open Access***

PHENOTYPIC DISTRIBUTION OF HUMAN MORPHOGENETIC TRAITS AND ABO-RH BLOOD GROUPS AMONG STUDENTS OF AMBA-GIORGIS SECONDARY AND PREPARATORY SCHOOL, WEGERA WOREDA, NORTHWEST ETHIOPIA

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(Received, 3rd August 2024 Accepted 1st September 2025, Published 12th September 2025)

Abstract *The morphogenetic traits or phenotypical traits are observable physical characteristics inherited from the parents, typically exhibiting autosomal recessive or dominant patterns and varying in expression among various populations. The current study aimed to evaluate phenotypic distribution of eleven morphogenetic traits alongside Rh blood group and ABO frequencies among the students at Amba Giorgis Secondary and Preparatory School. A descriptive cross-sectional study was conducted involving 384 volunteer students (176 males and 208 females) with the age range between 15 to 20 years, selected through stratified random sampling. Phenotypic data on morphogenetic traits were collected via direct physical observation. The blood samples were obtained through finger-prick, and Rh blood groups and ABO were determined using Slide agglutination technique using commercially prepared Anti-A, Anti-B, and Anti-D sera. Data were analyzed through SPSS version 23.0, while allelic frequencies of ABO blood groups were calculated through S2ABO software. The most prevalent morphogenetic traits in the studied population included smooth chin (77.6%), straight hairline (75.8%), attached earlobe (58.85%), crossing of the left thumb over the right thumb (57.03%), ability to roll the tongue (57.81%), right-handedness (97.7%), straight thumb shape (70.05%), absence of dimples (77.1%), crossing of the left arm over the right (88.28%), absence of mid-digital hair (73.44%), and normal foot arches (70.57%). The ABO blood group distribution followed the pattern O > A > B > AB, with blood group O being the most frequent (38.54%) and AB the least common (7.55%). Approximately 90% of the participants were Rh-positive. Significant sex differences were observed in the chin cleft/dimple, distribution of earlobe attachment, foot shape, thumb shape, facial dimple, and ABO blood groups. However, no significant association was found between ABO-Rh blood groups and morphogenetic traits. The study provides important baseline data on morphogenetic trait distribution and ABO-Rh blood group frequencies in this Ethiopian population. Significant associations were observed between several morphogenetic traits and sex, while no statistically significant association was observed between morphogenetic traits and ABO-Rh blood groups. These findings contribute to the understanding of genetic diversity in the region and provide a basis for further genetic, anthropological, and forensic studies.*

*[Citation: Belay, A., Munshia, A., Adisu, D., Abate, A. (2025). Phenotypic distribution of human morphogenetic traits and abo-rh blood groups among students of Amba-Giorgis secondary and preparatory school, Wegera Woreda, Northwest Ethiopia. J. Life Soc. Sci, **4**: 42]*
Keywords: *Amba Giorgis; ABO-Rh Blood group; Prevalence; Morphogenetic traits*

Introduction

Phenotypic variation in humans arises primarily from genetic differences, often in combination with environmental and behavioral influences (Johnson, 2007). Genetic variability is a fundamental characteristic of all living organisms, including humans (Weiss, 1993). Morphogenetic traits, which are observable physical characteristics inherited from parents, serve as visible expressions of this genetic diversity (Kooffreh et al., 2015). A trait refers to a distinct, observable feature of an organism, typically determined by one or more genes (Lai & Walsh, 1966). These genes are located on chromosomes

within the nucleus of every somatic cell, with each inheriting half of their genetic material from each parent (Razzaq et al., 2015).

Common human inherited traits include the presence or absence of dimples, earlobe attachment (attached or free), tongue rolling ability, thumb shape (straight or curved), hairline type (widow's peak or straight), chin type (cleft or smooth), handedness, blood group, and Rh factor (Onyije, 2012). Over 200 such traits are known to be inherited across generations; these traits follow either Mendelian (dominant/recessive) or non-Mendelian patterns of inheritance, contributing significantly to human diversity and evolutionary processes (Dennis, 2017). Phenotypic traits can be influenced not only by genetic inheritance but also by evolutionary mechanisms such as natural selection, genetic drift, gene flow, and environmental conditions (Ebeye et al., 2014; Mitchell-Olds et al., 2007).

Population genetics provides critical insights into ongoing human evolution and diversity. It also fosters understanding between different population groups by highlighting the genetic basis of human variation (Munir et al., 2015). Morphogenetic traits are particularly valuable in the study of human evolution, taxonomy, and biodiversity (Nwaopara et al., 2008a). Population diversity presents a unique chance to investigate morphogenetic variation among groups living under diverse geographical and ecological conditions (Nwaopara et al., 2008b).

Several studies have explored the distribution of ABO and Rh blood group phenotypes alongside simple inherited traits. Globally, blood group O and Rh-positive are the most common, while AB and Rh-negative are the least frequent (Pandey et al., 2013; Tesfaye et al., 2015). In Ethiopia, ABO blood group distribution typically follows the pattern O > A > B > AB, with group type O being most prevalent. Recent studies in South-Central Ethiopia estimate Rh-negative frequencies to range between 8–9% (Wogera Woreda Office of Agriculture and Rural Development, 2017).

To the best of our knowledge, no published data currently exists on the distribution of phenotypic variations of human morphogenetic traits and ABO and Rhesus (Rh) blood group phenotypes in the Wogera Woreda. Therefore, this study aims to assess the frequency and sex-based distribution of selected morphogenetic traits and ABO–Rh blood groups among students in Wogera Woreda.

Materials and methods

Study Area Description

The study was conducted among students at Wogera Secondary and Preparatory School between September 2019 and October 2020. Wogera is one of the *Woredas* (districts) located in the Amhara Regional State of Ethiopia, forming part of the Central Gondar Zone. Geographically, Wogera *Woreda* lies between latitudes 12°30′00″ and 13°00′00″ N, and longitudes 37°32′00″ and 38°10′00″ E. It is bordered by West Belessa to the south, Lay Armachiho to the west, Dabat to the north, and Janamora and East Belessa to the east. The woreda encompasses a total area of approximately 1,821.3 square kilometers, with a perimeter of about 255.9 kilometers (Wogera Woreda Office of Agriculture and Rural Development, 2017).

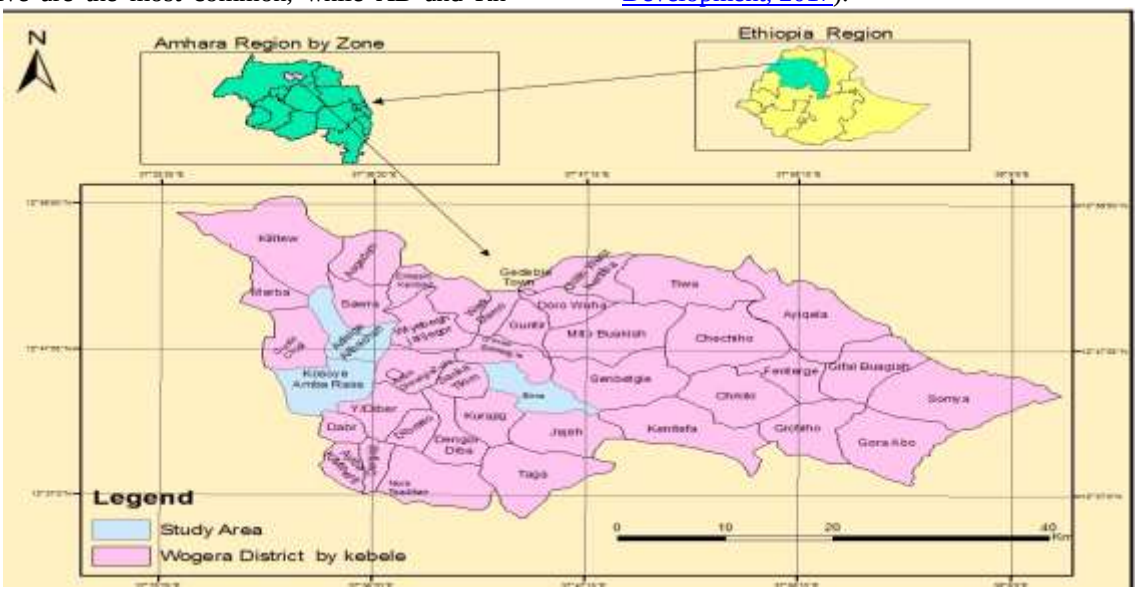

Figure1: map of the study area

Research Design

A descriptive, cross-sectional study design was employed to assess the frequency and distribution of genetically heritable morphogenetic traits and ABO–Rh blood group phenotypes among secondary and preparatory school students in Wogera District, Amhara Region, Ethiopia. The study focused on the following morphogenetic traits:

Trait	Dominant	Recessive
Hairline Shape	Widow's peak	Straight hairline
Earlobe Attachment	Free earlobes	Attached earlobes
Chin Type	Cleft chin	Smooth chin
Facial Dimples	Presence of dimples	Absence of dimples
Tongue Rolling	Ability to roll tongue	Inability to roll tongue
Arm Folding	Left arm over right	Right arm over left
Thumb Shape	Straight thumb	Bent (hitchhiker's) thumb
Thumb Crossing	Left thumb over right	Right thumb over left
Mid-Digital Hair	Presence of hair	Absence of hair
Handedness	Right-handedness	Left-handedness
Foot Shape	Normal foot arch	Flat foot
ABO Blood Group	Alleles A and B are co-dominant	O allele is recessive
Rhesus Blood Group	Rh-positive (presence of Rh-D)	Rh-negative (absence of Rh-D)

Source and study population

The source population for this study consisted of students enrolled at one preparatory and one secondary School located in Wogera District during the 2019/2020 academic year. The study population included students who voluntarily consented to participate in the research by responding to interviews, displaying their morphogenetic traits for observation, and providing blood samples for ABO and Rh blood group determination.

Sample size determination

To achieve the objectives of the study, a representative sample was selected using a stratified random sampling technique from a total population of 4,522 students enrolled in Grades 9 through 12 at Amba Giorgis Secondary and Preparatory Schools. Stratification was based on grade level to ensure proportional representation across the academic spectrum. The sample size was calculated using a single population proportion formula, assuming a 5% level of significance and a 95% confidence interval. Since no prior data existed on the distribution of morphogenetic traits and ABO and Rh blood groups in the study area, a prevalence (p) of 50% was used to maximize the sample size and minimize estimation error. The following formula was applied (Naing et al., 2006).

The formula was: $\mathbf{N = (Z^2 * p * (1 - p)) / d^2}$

Where N=the minimum required sample size

q=1-p=0.5

Z=1.96 at 95% confidence interval

d=margin of sampling error 5%=0.05

P= the probability was taken to be 50% for the calculation.

$N = (1.96)^2 0.5(1-0.5)/0.0025=384$. Therefore, the total sample size becomes 384 (176 were Males and 208 were females).

Thus, the minimum required sample size was determined to be 384 students.

Participant Recruitment and Sampling Procedure

Before blood sample collection, an orientation session was conducted with all students of Amba Giorgis Secondary and Preparatory Schools. The discussion focused on the objectives and benefits of the study, including the personal and public health advantages of knowing one's blood group in relation to nutrition, medical care, blood transfusion services, and voluntary blood donation. Following the awareness session, students were invited to voluntarily participate in the study. A total of 384 students consented to participate, providing both observable morphogenetic trait data and blood samples for ABO and Rh blood group determination. The study population consisted of 4,522 students, from which the sample of 384 was drawn using stratified sampling, followed by simple random selection within each stratum.

Stratification was based on grade level and sex, ensuring proportional representation from each group. To determine the proportional sample size from each grade level, the following formula was applied:

p=t/T=384/4522=0.0849 (p=stands for proportion, t=stands for total sample and T=stands for total population).

The number of students sampled from each grade level was calculated by multiplying the total number of students in each grade by the sampling proportion (0.0849): Grade 9: 2,166 × 0.0849 ≈ 184 students, Grade 10: 1,055 × 0.0849 ≈ 89 students, Grade 11: 953 × 0.0849 ≈ 81 students and Grade 12: 348 × 0.0849 ≈ 30 students. In addition to grade-level stratification, the samples were also proportionally distributed by sex. Based on the total number of male and female students in the study population: Males: 2,074 × 0.0849 ≈ 176 participants and Females: 2,448 × 0.0849 ≈ 208 participants

Blood sample collection was conducted between January and March 2020 at the health center laboratories in Amba Giorgis town by trained laboratory professionals.

Data Collection Technique

Collection of Data on Morphogenetic Traits

Data on morphogenetic traits were collected using standardized procedures, primarily through direct physical observation and simple performance-based assessments. Physical examination was conducted to determine the presence or absence of specific phenotypic traits, while some traits were assessed by asking participants to perform specific actions. For traits such as tongue rolling, arm folding, thumb crossing, and handedness, students were instructed to perform the relevant activity. For example, tongue rolling was assessed by asking individuals to attempt rolling the lateral edges of the tongue upward. Based on their ability, participants were categorized as either "rollers" or "non-rollers." Arm folding and thumb crossing were similarly assessed by observing which arm or thumb naturally rested on top, and handedness was determined by asking which hand the student preferred for writing or other dominant tasks.

Traits such as Head and Face Traits (Earlobe attachment, Facial dimples, Chin type, and Hairline pattern (widow's peak), Hands and Fingers (Thumb shape and Mid-digital hair) and Feet were evaluated through visual inspection by the researcher. Observations were conducted under good lighting conditions, and traits were recorded as either present or absent according to standardized criteria. All observations were documented systematically, and data were stratified by **sex** to allow for comparison of trait distribution between male and female students.

Principle of ABO Grouping and Blood Typing Procedure

ABO blood grouping is based on the principle of antigen–antibody interaction, specifically the agglutination (clumping) reaction that occurs when red blood cell (RBC) surface antigens interact with corresponding antibodies. If a specific antigen is present on the RBC membrane, mixing the blood with its corresponding antibody (anti-A or anti-B) results in visible agglutination. In contrast, the absence of the corresponding antigen leads to no agglutination (Dacie & Lewis, 2001).

ABO–Rh Blood Typing Procedure

The ABO and Rh blood types of participants were determined using the Slide agglutination technique using commercially prepared Anti-A, Anti-B, and Anti-D sera method with blood obtained via finger-prick. The procedure was conducted as follows:

The third (middle) finger of each volunteer was cleaned with cotton wool soaked in methylated spirit to sterilize the area and stimulate blood flow. After the finger dried, a sterile lancet was used to make a light prick. The first drop of blood was wiped away, and subsequent drops were collected. A clean, dry glass slide was divided into three regions**,** labeled A**,** B**,** and D**.** Anti-A serum was placed in region A. Anti-B serum was placed in region B. Anti-D serum (for Rh factor determination) was placed in region D. A drop of fresh blood was added to each region and mixed with the corresponding antisera using separate sterile sticks.

The slide was gently rocked and observed for agglutination (clump formation), which typically appears within a few seconds to minutes.

The result was interpreted as: Agglutination in region A only: Blood group A, Agglutination in region B only: Blood group B, Agglutination in both A and B: Blood group AB, No agglutination in A or B: Blood group O, Agglutination in region D: Rh-positive (Rh^+) and No agglutination in region D: Rh-negative (Rh^-)

Reliability and validity of generated data

To ensure the reliability of the data collected, careful attention was given during observation and recording of morphogenetic traits and blood typing results. Each step of the procedure was closely monitored, and three investigators cross-checked the findings to minimize observer bias and inconsistencies. By following standardized protocols and maintaining consistency in the methods used, the results were repeatable and consistent. Interpretations were monitored to reduce subjective classification or agglutination patterns. The validity of the generated data was ensured through the proper use of reagents (anti-A, anti-B, and anti-D antisera) and strict control of experimental conditions. To maintain internal validity, all variables other than the independent variable (i.e., the presence of a specific antigen or morphogenetic trait) were controlled.

Statistical Analysis of Data

Descriptive statistics were employed to summarize the demographic characteristics of the study population. The association between ABO and Rh-D blood groups and morphogenetic traits, as well as between blood groups and sex, was analyzed using the Chi-square X^2 test. All statistical analyses were conducted using SPSS software version 26. A p-value of ≤ 0.05 was considered statistically significant at a 95% confidence level. The distribution of ABO and Rh-D blood groups, along with morphogenetic trait frequencies, was presented using percentages and frequency tables. Furthermore, the allele and genotype frequencies for ABO and Rh-D blood groups were estimated using the S2ABO Estimator Software (Silva Square, Silvoa, Portugal) (Silva Square, n.d.), based on the Hardy-Weinberg equilibrium model**,** and expressed as percentages. The results related to human morphogenetic traits were displayed using both tables and figures for clarity and comparison.

Ethical Consideration and Informed Consent

Ethical approval for this study was obtained from the Ethical Clearance Committee of Bahir Dar University, College of Science. The research was conducted in accordance with established ethical guidelines to ensure the protection of participants' rights and well-being. Before participation, all students were informed about the objectives, procedures, and potential benefits of the study. Informed consent was obtained from each participant

before data collection began. Participation was entirely voluntary, and students were assured that the information collected would be used solely for research purposes and kept strictly confidential.

Result

Distribution of Morphogenetic Traits Among Study Participants

The analysis of morphogenetic trait distribution among the study population with the age range between 15 to 20 years revealed distinct patterns in trait prevalence. The following traits were observed with higher frequency: straight hairline, attached earlobes, smooth chin, absence of facial dimples, ability to roll the tongue, left-over-right arm crossing, straight thumb, left-over-right thumb crossing, absence of mid-digital hair, right-handedness, and normal foot arch. Conversely, traits such as the presence of facial dimples, the inability to roll the tongue, free earlobes, hitchhiker (bent) thumb, widow's peak hairline, presence of mid-digital hair, right-over-left thumb crossing, right-over-left arm crossing, cleft chin, flat foot, and left-handedness occurred at lower frequencies within the studied group. The study found that 291 participants (75.78%) exhibited a straight hairline, whereas 93 participants (24.21%) had a widow's peak hairline. Among those with a widow's peak, 47 individuals (50.54%) were male and 46 (49.46%) were female, indicating a relatively even distribution between sexes. The frequency of the widow's peak trait was therefore nearly equal among males and females. Among the 384 participants, attached earlobes were observed in 226 individuals (58.85%)**,** while free earlobes were found in 158 individuals (41.15%)**.** Of those with attached earlobes**,** 89 (39.38%) were male and 137 (61.62%) were female. In contrast, the free earlobe phenotype was more frequent among males (87, 55.06%**)** compared to females (71, 44.9%).

The cleft chin phenotype was present in 86 individuals (22.39%), while smooth chins were observed in 298 individuals (77.60%). Of those with cleft chins, 49 (56.98%) were male and 37 (43.02%) were female. A total of 88 participants (22.92%) exhibited facial dimples, whereas 296 (77.08%) did not. The trait was more common in males (58, 65.90%) than in females (30, 34.10%). Conversely, the absence of dimples was more prevalent among females (60.00%) than males (40.00%). The ability to roll the tongue was observed in 222 participants (57.81%), while 162 participants (42.19%) could not roll their tongues. Tongue rolling was more frequent in females (125, 56.30%) than in males (97, 43.70%). The non-rolling phenotype showed a nearly equal distribution between males (79, 48.77%) and females (83, 51.23%). The dominant phenotype, crossing the left arm over the right, was found in 339 individuals (88.28%), while 45 participants (11.72%) crossed their right arm over the left. Among those with the dominant phenotype, females comprised 182 (53.7%) and males 157 (46.3%). Similarly, the recessive phenotype was slightly more frequent in females (26, 57.8%) than in males (19, 42.2%). Detailed frequency values for each trait are presented in Table 1.

Table 1: Frequency distribution of morphogenetic traits among the study participants

Variable	Category	Frequency(N)	Percent (%)
Hair line	Widow's peak	93	24.21
	Straight	291	75.78
Ear attachment	Free	158	41.15
	Attached	226	58.85
Chin Cleft	Cleft	86	22.39
	Smooth	298	77.60
Facial dimple	Dimple	88	22.92
	No dimple	296	77.08
Tongue rolling	Able to roll	222	57.81
	Un able to roll	162	42.19
Crossing of arm	Left arm on the top	339	88.28
	Right arm on the top	45	11.78
Shape of thumb	Hitchhiker	115	29.95
	Straight	269	70.05
Crossing of thumb	Left thumb over right	219	57.03
	Right thumb over left	165	42.97
Mid-Digital hair	Present	102	26,56
	Absent	282	73.43
Handedness	Right	375	97.65
	Left	9	2.34
Foot	Normal	205	53.38
	Flat	179	46.61

Association between Morphogenetic Traits and Sex of Participants

Chi-square analysis was conducted to assess the association between selected morphogenetic traits and

the sex of participants. Among the traits analyzed, several showed statistically significant sex-based differences.

A significant difference was found in the earlobe attachment trait, where attached earlobes were more frequent among females (60.62%) compared to males (39.38%), while free earlobes were more common among males (55.06%) than females (44.94%) ($\chi2$=9.212, df=1,p=0.002, $\chi2$= 9.212, df = 1, p = 0.002, and χ^2 =9.212,df=1,p=0.002).

Similarly, the presence of a cleft chin was significantly more common in males (56.98%) than females (43.02%), whereas smooth chin traits were more frequently observed in females (57.38%) than males (42.62%) ($\chi2$=5.543, df=1, p=0.019, $\chi2$= 5.543, df = 1, p = 0.019, χ^2 =5.543, df=1, p=0.019).

The facial dimple trait also exhibited a highly significant association with sex. Dimpled faces were predominantly observed in males (65.9%) compared to females (34.1%), whereas females showed a higher proportion of non-dimpled faces (60.0%) ($\chi2$=18.320, df=1, p<0.001\chi^2 = 18.320, df = 1, p < 0.001, $\chi2$=18.320, df=1, p<0.001).

For the thumb shape, the Hitchhiker's thumb phenotype was significantly more frequent in males (59.13%) than females (40.87%), whereas the straight thumb shape was more common among females (60.0%) (χ^2 =11.692, df=1, p=0.001\chi^2 = 11.692, df = 1, p = 0.001, χ^2 =11.692, df=1, p=0.001).

The foot shape showed a highly significant variation with sex. The normal foot arch phenotype was more prevalent in males (65.36%) than in females (34.63%), while flat foot was predominantly observed in females (76.5%) compared to males (23.5%) ($\chi2$=67.583, df=1, p<0.001\chi^2 = 67.583, df = 1, p < 0.001$\chi2$=67.583, df=1, p<0.001).

Other traits such as hairline shape**,** tongue rolling ability**,** arm and thumb crossing preferences**,** mid-digital hair, and handedness did not show statistically significant differences between sexes (p > 0.05), although some trends were observed. For instance, tongue rolling ability was slightly more common in females (56.3%) than males (43.7%), and right-handedness was almost universal (97.7%) across both sexes (Table 2).

Table 2: Association of Morphogenetic traits and ABO-Rh blood group system with Sex of Participants

Morphogenetic traits	Sex of Participant		Total N (%)	χ^2 (DF)	p-value
	Male (%)	Female (%)			
Hair line shape traits					
Widow's peak	47(50.54)	46(49.46)	93(100)		
Straight	129(44.33)	162(55.67)	291(100)	1.09 (1)	0.29
Ear attachment					
Free	87(55.06)	71(44.94)	158(100)		
Attached	89(39.38)	137(60.62)	226(100)	9.21 (1)	<0.01
Chin cleft /Dimple					
Cleft	49(56.98)	37(43.02)	86(100)		
Smooth	127(42.62)	171(57.38)	298(100)	5.54(1)	<0.05
Dimple					
Present	58(65.91)	30(34.09)	88(100)		
Absent	118(40.00)	178(60.00)	296(100)	18.32(1)	<0.01
Tongue rolling					
Able to roll	97(43.70)	125(56.30)	222(100)		
Un able to roll	79(48.77)	83(51.23)	162(100)	0.97 (1)	0.33
Crossing of arm					
Left arm on the top	157(46.31)	182(53.69)	339(100)		
Right arm on the top	19(42.22)	26(57.78)	45(100)	0.27(1)	0.61
Shape of thumb					
Hitchhiker	68(59.13)	47(40.87)	115(100)	11.69(1)	<0.01
Straight	108(40.00)	161(60.00)	269(100)		
Crossing of thumb					
Left thumb over right	91(41.55)	128(58.45)	219(100)		
Right thumb over left	85(51.52)	80(48.48)	165(100)	3.76(1)	0.05
Mid digital hair					
Present	51(50.00)	51(50.00)	102(100)		
Absent	125(44.33)	157(55.67)	282(100)	0.97(1)	0.32
Handedness					
Right	173(46.13)	202(53.87)	375(100)		
Left	3(33.33)	6(66.67)	9(100)	0.58(1)	0.45
Foot					
Normal	134(65.36)	71(34.63)	205(100)		

Flat	42(23.46)	137(76.54)	179(100)	67.58(1)	<0.01

Frequency Distribution of ABO and Rh (D) Blood Groups

Among the study population, blood group O was the most prevalent, accounting for 38.54% of participants, followed by blood group A (31.51%)**,** B (22.40%)**,** and AB (7.55%). Thus, blood type O was the most common, while AB was the least frequent within the sampled population. The distribution of blood groups B, AB, and O appeared relatively balanced across both sexes. However, blood group A was notably more predominant among females (66.1%) compared to males (33.9%), indicating a significant sex-based difference in the distribution of this particular blood type. With respect to the Rhesus (Rh) factor, a substantial proportion of the population 342 individuals (89.06%), were Rh-positive, while only 42 participants (10.94%) were Rh-negative. The distribution of Rh positivity and negativity was fairly similar across sexes. Among Rh-positive individuals, 158 (46.2%) were male and 184 (53.8%) were female. In the Rh-negative group, 18 (42.86%) were male, while 24 (57.14%) were female (Table 3).

Table 3: ABO-Rh group frequency distribution among the study participants

Variables	Sex of Student		Total
	Male	Female	
ABO blood group			
A	41(33.88)	80(66.12)	121(100)
B	44(51.16)	42(48.84)	86(100)
AB	15(51.72)	14(48.27)	29(100)
O	76(51.4)	72(48.6)	148(100)
Rh-blood group			
Rh (+)	158(46.19)	184(53.81)	342(100)
Rh(-)	18(42.86)	24(57.14)	42(100)

Association between Morphogenetic Traits and ABO Blood Groups

Chi-square analysis was conducted to determine whether there were statistically significant associations between ABO blood groups and various morphogenetic traits in the study population. No significant association was found between hair line shape (widow's peak or straight) and ABO blood groups ($\chi^2 = 3.660$, $p = 0.301$). The distribution of free and attached earlobes did not significantly vary across ABO blood types ($\chi^2 = 2.747$, $p = 0.432$). No significant relationship was observed ($\chi^2 = 1.010$, $p = 0.799$), indicating that chin phenotype distribution is independent of blood group. The presence or absence of facial dimples approached but did not reach statistical significance ($\chi^2 = 6.714$, $p = 0.082$), suggesting a possible trend worth exploring in larger samples. There was no significant association between tongue rolling ability and ABO blood group ($\chi^2 = 0.371$, $p = 0.946$). The preference for crossing the left or right arm on top showed no significant difference among blood groups ($\chi^2 = 2.783$, $p = 0.426$). Although not statistically significant, thumb shape distribution approached significance ($\chi^2 = 6.694$, $p = 0.082$), suggesting a weak trend toward association. No significant difference was observed in crossing thumb preference across ABO groups ($\chi^2 = 0.843$, $p = 0.839$). The presence or absence of mid-digital hair did not significantly correlate with ABO blood group ($\chi^2 = 2.651$, $p = 0.499$). Right or left-handedness showed no significant relationship with ABO blood group ($\chi^2 = 6.496$, $p = 0.370$). The distribution of normal and flat foot types across blood groups was not statistically significant ($\chi^2 = 4.591$, $p = 0.204$) (Table 4).

Table 4: Association of morphogenetic traits with ABO blood group

Morphogenetic trait	ABO blood group				χ^2 (DF)	P-value
	A	B	AB	O		
	N (%)	N (%)	N (%)	N (%)		
Hair line						
Widows peak	28(30.11%)	17(18.27%)	5(5.37%)	43(46.24%)	3.660	0.301
Straight	93(31.95%)	69(23.71%)	24(8.25%)	105(36.08%)		
Earlobe attachment						
Free	44(27.85%)	40(25.32%)	13(8.23%)	61(38.61%)	2.747(3)	0.432
Attached	77(34.07%)	46(20.35%)	16(7.09%)	87(38.49%)		
Chin trait						
Cleft	24(27.91%)	22(25.58%)	7(8.14%)	33(38.37%)	1.010(3)	0.799
Smooth	97(32.55%)	64(21.47%)	22(7.38%)	115(38.59%)		

Facial dimple						
Present	99(33.56%)	62(21.02%)	18(6.10%)	116(39.32%)	6.714(3)	0.082
Absent	22(24.72%)	24(26.96%)	11(12.36%)	32(35.96%)		
Tongue rolling						
Able to roll	49(30.25%)	38(23.46%)	13(8.02%)	62(38.27%)	0.371(3)	0.946
Un able to roll	72(32.43%)	48(21.62%)	16(7.21%)	86(38.74%)		
Crossing of arm						
Left arm on top	103(30.47%)	77(22.77%)	27(7.98%)	131(38.76%)	2.783(3)	0.426
Right arm on top	18(39.13%)	9(19.57%)	2(4.35%)	17(36.96%)		
Shape of thumb						
Curb	27(23.47%)	32(27.82%)	7(6.08%)	49(42.61%)	6.694(3)	0.082
Straight	94(34.9%)	54(20.1%)	22(8.2%)	99(36.8%)		
Crossing of thumb						
Left thumb over right	66(30.14%)	48(21.92%)	18(8.22%)	87(39.73%)	0.843(3)	0.839
Right thumb over left	55(33.33%)	38(23.03%)	11(6.67%)	61(36.97%)		
Mid digital hair						
Present	87(30.85%)	65(23.05%)	18(6.38%)	112(39.72%)	2.651(3)	0.499
Absent	34(33.33%)	21(20.59%)	11(10.78%)	36(35.29%)		
Handedness						
Right	118(31.46%)	84(22.40%)	28(7.46%)	145(38.67%)	6.496(3)	0.370
Left	3(33.33%)	2(22.22%)	1(11.11%)	3(33.33%)		
Foot trait						
Normal	55(26.83%)	50(24.39%)	17(8.29%)	83(40.48%)	4.591(3)	0.204
Flat	66(36.87%)	36(20.11%)	12(6.70%)	65(36.31%)		

Allelic and Genotypic Frequencies of the ABO Blood Group

The allelic frequencies of the ABO blood group system were estimated using the S2ABOEstimator software (Silva Square, Silvoa, Portugal). Among the three alleles, the O allele (r**)** was the most prevalent with a frequency of 0.6182, followed by the A allele (p = 0.2190**)** and the B allele (q = 0.1628). The Hardy-Weinberg log-likelihood value was 484.5158, indicating that the population was in Hardy-Weinberg equilibrium. No statistically significant deviation was observed in the allele distribution (p = 0.7016. The genotypic frequencies were AA (p^2) = 0.04796, AO (2pr) = 0.2707, BB (q^2) = 0.0265, BO (2qr) = 0.2013, AB (2pq) = 0.0713 and OO (r^2) = 0.3822 (Table 5).

Table 5: Allelic and genotypic frequency of ABO-Rh blood group of the study participants

Gene/allele	Frequency	Genotype	Frequency	Phenotype	Frequency/%
A(p)	0.2190	AA(P2)	0.04796	A	4.796%
B(q)	0.1628	AO(2pr)	0.2707	A	27.07%
O(r)	0.6182	BB(q2)	0.02645	B	2.645%
		BO(2qr)	0.2013	B	20.13%
		AB(2Pq)	0.0713	AB	7.13%
		OO(r2)	0.3822	O	38.22%

Discussion

Human variation encompasses a broad spectrum of phenotypic and genotypic traits influenced by complex interactions between genetic, environmental, and sociocultural factors (Larsen, 2014). This variation is evident not only in cognitive and immunological differences but also in morphogenetic traits such as earlobe attachment, chin type, facial dimples, thumb shape, mid-digital hair, and handedness. These observable features, along with the well-established ABO and Rh blood group systems, serve as important markers for understanding genetic diversity within and across populations. In the current study, the distribution patterns of these traits among students of Wogera Secondary and Preparatory School reflect both universal trends and population-specific characteristics. For example, the predominance of dominant traits like attached earlobes, straight thumb shape, and right-handedness aligns with global observations, while the higher prevalence of recessive traits such as smooth chin and straight hairline highlights local genetic variation. Similarly, the ABO blood group distribution followed the global pattern of O > A > B > AB, and Rh-positive individuals constituted the majority, reaffirming the widespread dominance of the Rh(D) allele. This variability arises from the complex interplay between genetic and environmental factors (Özyiğit, 2020). Due to sexual dimorphism, many phenotypic traits differ not only across populations but also between males and females (Ordu & Agi, 2014). In this context, the present study aimed to assess the

phenotypic distribution of selected morphogenetic traits, along with ABO and Rh blood group frequencies, among students of Wogera Secondary and Preparatory School.

Head and Face Traits

Earlobe attachment

The frequency distribution of the attached earlobe phenotype was higher (58.85%) compared to the free earlobe (41.15%) in the studied population. This finding is in agreement with previous reports from different regions. For instance, studies conducted in Wales and among Filipino (65.3%; Lai & Walsh, 1966) and Japanese (67.1%; Lai & Walsh, 1966) populations, a study from Pakistan also reported a predominance of attached earlobes (Das et al., 2001). Similarly, a study in Calabar, Nigeria found a higher incidence of attached (69.2%) than free (30.8%) earlobes (Kooffreh et al., 2015). In contrast, other studies reported differing patterns. A study in Nigeria found that free earlobes were more common (61.8%) than attached earlobes (38.2%; Razzaq et al., 2015). Likewise, a study from India reported a much higher frequency of free earlobes (83.65%) compared to attached (16.35%) among the Assamese Sikh population (Singh & Sengupta, 2004). Ordu and Agi (2014) also reported a higher prevalence of free earlobes (74.17%) in Calabar, Nigeria. In terms of sex distribution, free earlobes were more common in males (55.06%) than in females (44.94%), while attached earlobes were more frequent in females (60.62%) compared to males (39.38%). Chi-square analysis revealed a statistically significant association between earlobe attachment type and sex ($p = 0.002$). This finding was consistent with findings of several studies (Nwaopara et al., 2009; Das et al., 2001; Razzaq et al., 2015).

Chin Morphology

In the present study, smooth chin morphology was observed in the majority of participants, accounting for 77.6% of the total population, while 22.4% exhibited a cleft chin. Statistical analysis revealed a significant association between chin type and sex ($p < 0.05$). Cleft chin was more prevalent among males (56.98%), whereas smooth chin was more frequently observed in females (57.38%). These findings were consistent with those reported by a study from Pakistan that indicated smooth chin morphology was more commonly observed in females (79.2%) than in males (67.2%), and cleft chin was more prevalent among males (32.8%) compared to females (20.8%; Munir et al., 2015). This pattern supports the notion of sexual dimorphism in chin morphology across different populations.

Facial dimple

In the present study, facial dimples were observed in approximately 22.9% of the participants, while the majority (77.1%) exhibited no dimples. A statistically significant association was found between sex and the presence of facial dimples ($p < 0.05$), with a higher prevalence in males (65.9%) compared to females (34.1%). This pattern can be explained by a combination of genetic, anatomical, and hormonal factors. Our finding aligns with a study conducted in Hawasa, Ethiopia, which reported a facial dimple prevalence of 33.12%, with 66.88% lacking dimples (Dagnew, 2015). Conversely, our results differ from studies conducted in various populations worldwide. For instance, lower frequencies of facial dimples were reported in Ekpoma, Nigeria (Nwaopara et al., 2008b), Quetta, Pakistan (Dagnew, 2015), Calabar, Nigeria (Razzaq et al., 2015), and among the Niger Deltans of Nigeria (Anibor, 2016).

Tongue rolling

In this study, a greater proportion of students were able to roll their tongues (57.81%) compared to those who could not (42.19%). This finding is consistent with previous studies conducted among the Sikh population in India (Singh & Sengupta, 2004), residents of Ekpoma, Nigeria (Nwaopara et al., 2008a), South-South Nigerians (Razzaq et al., 2015), various South Nigerian ethnic groups (Dennis, 2017), and students from North Gondar, Ethiopia (Worede, 2018). Females demonstrated a higher frequency of tongue rolling ability (56.30%) than males (43.7%), although no statistically significant association was found between sex and tongue rolling phenotype ($\chi^2 = 0.971$, $p = 0.325$). These results are supported by Singh and Sengupta (2004) and Dennis (2017), who also reported similar gender distributions. Additionally, Usha et al. (2016) documented a higher prevalence of the dominant tongue rolling trait among females compared to males.

Hands and Fingers

Crossing of arm

The frequency of individuals crossing their left arm over their right arm was notably higher (88.28%) compared to those crossing their right arm over their left (11.72%) in the studied population. Both phenotypes; left arm over right and right arm over left were more commonly observed in females (53.7% and 57.8%, respectively) than in males (46.3% and 42.2%, respectively). However, chi-square analysis revealed no statistically significant difference in the distribution of these phenotypes between males and females ($\chi^2 = 0.268$, $df = 1$, $p = 0.605$). These findings align with those of Singh and Sengupta (2004) in the Assamese Sikh population, who also reported a higher prevalence of left-arm-over-right crossing and found no significant sex-based differences for this trait.

Shape of thumb

In this study, the straight thumb shape was more prevalent (70.05%) compared to the hitchhiker's thumb shape (29.95%). This finding was consistent with findings reported by Bamshad et al. (2004) and Kooffreh et al. (2015). In contrast, a study conducted in Quetta, Pakistan, observed nearly equal frequencies of hitchhiker's thumb (49.4%) and straight thumb (50.6%; Munir et al., 2015). In the present study, the straight thumb shape was more common among males (59.13%) than females (40.87%), whereas the

hitchhiker's thumb shape was more frequent in females (60.00%) compared to males (40.00%). A significant association was found between thumb shape and sex ($\chi^2 = 11.692$, df = 1, p = 0.001), which aligns with the results of a study in Pakistan (Munir et al., 2015). This could be attributed to genetic, hormonal and developmental influences.

Crossing of Thumb

The dominant trait of crossing the left thumb over the right was observed more frequently (57.03%) than the recessive trait of crossing the right thumb over the left (42.97%) in the study population. The occurrence of the recessive phenotype was nearly equal between males (51.52%) and females (48.48%), whereas the dominant phenotype was more prevalent in females (58.45%) compared to males (41.55%). Chi-square analysis indicated no statistically significant association between thumb crossing and sex (p = 0.052). These findings were consistent with a study in India that found no sex-related differences in thumb crossing (Warghat et al., 2011; Prabhakar, 2005). Conversely, studies in India documented a higher prevalence of left thumb crossing in females (Mitchell-Olds et al., 2007) and overall higher frequency of left thumb crossing in females (Winchester, 1979).

Occurrence of Mid-Digital Hair

In this study, the presence of mid-digital hair was relatively low (26.56%), with the majority (73.44%) lacking hair on the mid-digital fingers. This result was in agreement with findings from Indian (Bhasin & Chahal, 1996) and Ghanaian populations (Benjamin et al., 2013), both of which reported a higher frequency of mid-digital hair absence. In contrast, a study in Nigeria reported a predominance of mid-digital hair presence (92%) among families (Kooffreh et al., 2015). Sex-wise distribution of mid-digital hair was equal among males and females (50% each), and no significant association with sex was observed. Similar findings were reported by a study from Ethiopia, Nigeria and Ghana (Worede, 2018; Kooffreh et al., 2015). However, some studies indicated a higher frequency of mid-digital hair in males (Benjamin et al., 2013; McDonald, 2011), which may be influenced by environmental factors such as manual labor and hair follicle wear in females, as well as geographic, climatic, occupational, and genetic differences.

Handedness

Handedness, or the preferential use of one hand over the other for tasks like writing or throwing, predominantly favors the right hand globally, with approximately 90% of individuals being right-handed (Gilbert & Wysocki, 1992; Scharoun & Bryden, 2014; Papadatou-Pastou et al., 2020). In this study, 97.7% of participants were right-handed, while 2.3% were left-handed. This prevalence aligns with studies conducted worldwide (Munir et al., 2015; Chandha & Sandhu, 2013; Bhasin & Chahal, 1996) but is lower than the commonly reported 10% prevalence of left-handedness (Gilbert & Wysocki, 1992; Medland et al., 2005; Vuoksimaa et al., 2010; Peters et al., 2006). Females showed a slightly higher proportion of right-handedness (53.87%) than males (46.13%), and left-handedness was also more frequent in females (66.67%) than males (33.33%). However, no statistically significant association was found between handedness and sex (p = 0.446), corroborating Tan's (1988) findings of sex-related handedness tendencies.

Shape of hair line

Analysis of the distribution of hairline shapes in the sampled population revealed a higher prevalence of the straight hairline (75.78%) compared to the widow's peak (24.22%). This finding is consistent with the results from Nigeria that reported a predominance of the straight hairline (86.3%) and a lower frequency of the widow's peak (13.7%) among a Nigerian population (Ordu & Agi, 2014). Given that the straight hairline is considered a recessive trait and the widow's peak a dominant one, the current data suggest a higher occurrence of the recessive phenotype within the study population. However, this contrasts with findings by Nusbaum and Fuentefria (2009) and a study from Spain (Ceballos et al., 2013), which reported a markedly higher frequency of the widow's peak 81% and 94%, respectively, in female subjects. Similarly, a study among Nigerians reported a more balanced distribution of straight and widow's peak hairlines, at 57.78% and 42.09%, respectively (Nwaopara et al., 2009). These discrepancies may be attributed to factors such as genetic drift, mutation, natural selection, and population migration. In the present study, the distribution of hairline types between males and females showed no significant difference, as confirmed by chi-square analysis, indicating that hairline shape is not sex-linked. This finding diverges from earlier studies, which reported sex-based variation in the expression of hairline traits (Nusbaum & Fuentefria, 2009; Ceballos et al., 2013).

Foot Arch Type

In the current study, normal foot arches were more common (53.40%) than flat feet (46.60%). Normal arches were notably more prevalent in males (65.36%) compared to females (34.64%), while flat feet were more frequent in females (76.5%) than males (23.5%). This sex-based distribution difference was statistically significant (p = 0.000). These results concur with a study from Morelia, Mexico, where flat feet prevalence was 31.9% in preschool children and 8.8% in school-aged children (Arizmendi et al., 2004). Contrarily, Prętkiewicz-Abacjew and Opanowska (2013) found a higher frequency of flat feet in boys than girls, while studies from Tri-City, Poland, reported that the majority of children had normal longitudinal foot arches. Literature generally focuses more on the longitudinal arch and less on the transverse arch or toe positioning (Prętkiewicz-Abacjew & Opanowska, 2013).

Distribution of ABO and Rh Blood Groups

The distribution of ABO blood groups in the studied population followed the order O > A > B > AB, with frequencies of 38.54%, 31.51%, 22.39%, and 7.55%, respectively. This trend aligns with previous reports from various Ethiopian populations (Tesfaye et al., 2015; Alemu & Mama, 2016; Golassa et al., 2017) and other global populations that commonly report group O as the most frequent and AB as the least frequent (Nwaopara et al., 2008b; Boskabady et al., 2005; Adeyemo & Soboyejo, 2006; Apecu et al., 2016; Dali et al., 2011).

Although the frequency of blood group B varies across populations, with some studies reporting a higher prevalence of group B than A (Dali et al., 2011; Nwaopara et al., 2008b), the present study observed a relatively similar distribution of groups B, AB, and O between sexes. However, blood group A was significantly more frequent in females (two-thirds) than in males (one-third), possibly due to sample size limitations. A significant association between ABO blood group distribution and sex was found ($p = 0.017$). These findings are comparable to studies in different Ethiopian regions (Tesfaye et al., 2014; Teshome et al., 2019; Enawgaw et al., 2022; Teklu & Shiferaw, 2016; Tewodros et al., 2011). Similar global distributions are noted among African-Americans, Caucasians in the US, Western Europeans, Nepalese, and Mexicans (Adeyemo & Soboyejo, 2006; Canizalez-Román et al., 2018; Upadhyay-Dhungel et al., 2013). In contrast, populations in Pakistan have shown differing distributions, such as B > A > O > AB (Khan et al., 2009; Khattak et al., 2008).

Distribution of Rh (D) factor

In this study, most (89.06%) of the participants were Rh+ while only 10.84% were Rh^-, which agrees with most studies conducted in different parts of the world, including Ethiopia, though the figures may vary significantly (Boskabady et al., 2005; Jaf, 2010; Alemu & Mama, 2015; Kooffreh et al., 2015; Tesfaye et al., 2015; Muhammad & Mama, 2015; Butt et al., 2016; Alabdulmonem et al., 2020). This can be attributed to genetic dominance, evolutionary advantage and population genetics. The frequency distribution of Rh blood types between male and female individuals was relatively similar and no statistically significant association was found between Rh factor and gender ($p=0.682$). This finding was consistent with various studies that reported the Rh blood type distribution does not significantly differ by gender ($p > 0.05$; Ahmed et al., 2016; Bashwari et al., 2001; Eze et al., 2004).

Allelic Frequencies of ABO Blood Groups

In this study, the allelic frequencies for the ABO blood group system were O (r) = 0.6182, A (p) = 0.2190, and B (q) = 0.1628. These values closely align with the findings of a study in the Silte zone of Ethiopia, which reported allelic frequencies of O (0.65), A (0.19), and B (0.15; Tesfaye et al., 2014). The observed allelic frequency pattern, IO>IA>IB, is consistent with a study from Ethiopia that documented similar frequencies in the Arsi clan (A = 0.19, B = 0.16, O = 0.65), Guji clan (A = 0.21, B = 0.16, O = 0.63), and Borena clan (A = 0.22, B = 0.15, O = 0.63; Ahmad, 2013). However, allelic distributions from the Indian subcontinent show some variation; A (p) = 0.154, B (q) = 0.249, and O (r) = 0.591, differing slightly from the current findings (Mastana & Papiha, 2004).

Genotypic Frequencies of ABO Blood Groups

The study identified six genotypic classes; the genotypic frequencies were AA ($p^2=0.04796$), AO ($2pr=0.2707$), BB ($q^2=0.0265$), BO ($2qr=0.2013$), AB ($2pq=0.0713$) and OO ($r^2=0.3822$). The homozygous OO genotype was the most common, representing 38.22% of the population. The predominance of the IO allele likely reflects its presence in heterozygous forms (IAIO and IBIO) alongside homozygous OO individuals. Chi-square analysis of ABO blood group distribution yielded a value of 0.4078 with 3 degrees of freedom, corresponding to a p-value between 0.90 and 0.95 ($p > 0.90$), indicating no significant deviation from Hardy-Weinberg equilibrium, consistent with global patterns of IO allele dominance in heterozygous forms (IAIO, IBIO; Cavalli-Sforza et al., 1994; Mourant et al., 1976; Yamamoto et al., 1990; Yip, 2002).

Conclusion

This study revealed that among the 11 morphogenetic traits analyzed, dominant phenotypes such as right-handedness, left arm crossing over the right, straight thumb shape, attached earlobe, tongue rolling ability, left thumb crossing over right, and normal foot arch were predominant in the Amba Giorgis student population. Conversely, recessive traits like smooth chin, absence of facial dimples, straight hairline, and absence of mid-digital hair were also commonly observed. The ABO blood group distribution followed the global pattern of O > A > B > AB, with blood group O being the most frequent and AB the least. Rh-positive status was highly prevalent, consistent with worldwide data. Although no association was detected between morphogenetic traits and the combined ABO-Rh system, a statistically significant association between ABO blood group and sex ($p = 0.017$) underscores the importance of considering sex-based differences in population genetic studies. Furthermore, distinct allele frequency distributions reported in various Ethiopian ethnic groups reflect the substantial genetic diversity present within the country. These findings provide valuable baseline data on genetic and morphogenetic trait distribution in this Ethiopian population and may inform future anthropological, medical, and genetic studies. The observed sex-based association with ABO blood groups emphasizes the importance of incorporating gender as a variable in genetic research. Moreover, the variation in allele frequencies across Ethiopian ethnic groups underscores the country's rich genetic diversity,

suggesting that population-specific data are crucial for informed medical, anthropological, and genetic studies. This study therefore contributes important baseline information for future research and public health planning in Ethiopia.

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Declaration

Authors' Contributions

The corresponding author (AA) was involved in the conception, design, drafted the present manuscript and data analysis. All authors (AB, AM, DA, AA) were involved in analysis and interpretation of data. AA (corresponding author), AB and AM have been involved in critically revising the manuscript for important intellectual content.

Conflicts of Interest: The authors declare that they have no competing interests.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from Institutional review board of Bahir Dar University. Written informed consent was ensured from all study participants to take part in the study voluntarily after they get informed about the objective and purpose of the study. This study was performed in accordance with the Declaration of Helsinki.

Availability of data and materials: All the generated data in this article are included in the manuscript. The original data can be obtained from the principal investigator upon request Alemayehu Abate alexu2love@gmail.com

Funding: No funding was given to support this study