4-1-2012

Microgeographic differentiation in historical Yemen inferred by morphometric distances

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Key words: Microgeographic differentiation, morphometric distances, historical Yemen.

Running title: Microgeographic differentiation in historical Yemen

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ABSTRACT

This study analysed the variations in space of 8 body dimensions and 11 measures of the head of 1,244 adult Yemenite males, collected in 1933/34 by Coon in Yemen and in Hadhramawt. The aim was to evaluate the presence of geographic microdifferentiation of the populations settled in the different regions of Yemen at the time. Coon sub-divided the sample into 6 geographical areas according to birthplace and ethnicity of the individuals: Tihamah, the Western Mountains, the Central Plateau, the South Coast, the Eastern Mountains and Hadhramawt. The results of ANCOVA (age as covariate) show that the observed differences of all variables among the six groups were highly statistically significant. Tukey's post-hoc test reveals higher statistically significant differences among four main groups: 1) Tihamah; 2) the Western Mountains and Central Plateau; 3) the Eastern Mountains; 4) the Southern Coast and Hadhramawt. Multiple discriminant analysis carried out using only the data of the 11 measures of the head, the more 'genetically' determined variables, confirmed these differences. Indeed, the first canonical variate well separates the groups with the Tihamah, Southern Coast and Hadhramawt on the one side and the Eastern Mountains, Western Mountains and Central Plateau on the other. The second canonical variate separates the Tihamah, Western Mountains and Central Plateau from the Eastern Mountains, Southern Coast and Hadhramawt. In conclusion, the Yemenite population seems to be composed of three morphologically distinct groups and an Eastern Mountains group which is positioned between the group formed by the Southern Coast and Hadhramawt and the Western Mountains and Central Plateau group. The Tihamah is the most distant from all the other groups. These differences are probably due to the presence/absense of geographical and cultural barriers that have favoured/blocked the gene flow over the years. Indeed, the entire coastal belt, through the centuries, has constituted one of the principal commercial routes between the East, Africa and the eastern Mediterranean, while the high inland mountains have isolated the remaining communities. This data is also confirmed by genetic studies. Finally, the average height (162.6 cm) of the global Yemenite population, compared to data from the other 6 middle-eastern Arab countries and Egypt, was found to be 3-6 cm less. This characteristic will be further studied analysing variations in average height according to the different age classes in order to evaluate any possible secular changes.

Introduction

Geographically, Yemen links Arabia to the Horn of Africa. It is separated by the Rub'al-Khali desert from the former, and by the Red Sea acrosss the Bâb al-Mandib straits from the latter. The Country was characterized by a high level of internal geographic isolation, caused by a combination of impervious mountains and deserts. However, for many years in the coastal areas, there was also a considerable flow of people involved in commercial activities along caravan routes. There are historical documents which mention the existence of commercial traffic since ancient times towards various areas of Asia, of the Mediterranean Basin and India. This might have caused gene flow from these areas for a long period of time. There are also documents which testify various invasions in different periods of populations from the northern areas and the Ethiopian-Abyssinian areas (Giuffrida-Ruggeri, 1913, 1915, 1920; Seligman, 1917; Keith e Krogman, 1932; Van Beek, 1970; Richard, 1984). These factors mean that the study of the biologoical history of these populations are of particular interest.

However, there are few anthropological studies carried out in Yemen in the last two centuries, because of its cultural and geographical isolation. Most of this research was performed on the anthropometry of the living populations, and very often on a very limited number of subjects. It is worth noting the following studies: Hildebrandt (1879), Mochi (1907), Duckworth (1912), Leys and Joyce (1913), Cipriani (1930-31; 1938), Thomas (1929; 1931; 1932), Keith and Krogman (1932). These researchers aimed to define the so-called “classic Arab type” classifying them according to the system of “races” elaborated by various authors. Furthermore, there was particular interest in the existence of external elements due to mixing with other “racial” groups.

The objective of the present research was to evaluate the presence of biological microdifferentiation of the groups that settled in the various areas of Yemen in the early 1930s. This was done through the analyses of the anthropological records collected between 1933 and 1934 by Carlton S. Coon, currently kept at the National Anthropological Archives of the Smithsonian Institution of Washington D.C. (Coon, 1933-1934). Even though it is not recent data, it however remains the only anthropological investigation carried out in Yemen and the biggest research project ever carried out on Arab populations.

The reconstruction of the biological microdifferentiation of the population is of particular anthropological importance because it is the final product of the historical peopling of this area. Furthermore, it will represent the basis for further studies on the biological evolution of these

populations.

Materials and methods

The dataset

The dataset includes 1,452 anthropological forms collected in 1933/34 by Coon in Yemen and in Hadhramawt (Coon, 1933-1934). The original forms are preserved at the National Anthropological Archives of the Smithsonian Institution, Washington D.C., where they were copied by one of the Authors (A.C.). Concerning the reliability of the data, Coon (1981) states that the survey was prepared very accurately, and the forms actually reflect it. This material has been studied only partially. Coon (1939) published some few descriptive statistics of several measures and indeces, and some percentages of the morphological characteristics of 400 individuals of the "Central Plateau" and Oschinskyn (1954) studied a number of "Coastal Yemen" individuals.

The forms are organized in three sections. The first section includes name, sex, birthplace, 'Tribe or District', occupation, professed religion, and principal spoken language. The second reports age, blood group, 11 somatic and 13 cephalic measurements, and several anthropometric indeces. The third section of the form contains the qualitative classification of 29 morphological traits, e.g. skin and eye colour, form of the head and face.

According to the declared occupations, the sample is composed by cameleers /coolies of salt (28.5%), soldiers (27.9%), farmers and shepherds (21.2%), sailors (18.3%), and employees and shop keepers (4.1%).

The database comprises 1344 male subjects of certain Yemenite origin, 95 of which wee less than 20 years of age and therefore excluded from later analyses. There were also 73 individuals born in Kuwait and 35 natives from other countries and/or of mixed ancestry. Both these groups were excluded from the analyses.

Coon divided Yemen into 6 geografichal areas, according to birthplace and tribe (Figure 1):

1) the Tihamah, or "Coastal Yemen", the western coastal region. There are 284 files for this area;

2) the "Western Mountains", for which there are 114 individuals;

3) the "Central Plateau", which constitutes the largest group with 333 individuals;

4) the "Eastern Mountains", which once were the southern border of Northern Yemen for which there are 318 indivuals;

5) the "Coastal zone", of Aden, which corresponds with the most western part of the southern coast,

with 46 individuals;

6) Hadhramawt, the eastern part of southern Yemen with 249 individuals.

Finally, 40 files have been included in the database which were compiled by Cipriani in 1927 in Yemen, (Moggi-Cecchi, private collection; Cipriani, 1930-1931; 1938). Of these, only 31 regard adult subjects and the data was analysed separately in order to carry out coeval comparisons.

The metric data considered in this study total 19: 8 somatic and 11 of the head (the list is reported in Table 1). The number for each group in Table 1 is due to the fact we considered only individuals who were at least 20 years of age for whom all the 19 measurements were available.

Statistical analyses

The descriptive statistics of all somatic traits were calculated in the global sample and for each geographical area. ANCOVA (age as covariate) was used to evaluate significant differences for the anthropometric variables among the six groups and Tukey's HSD for unequal sizes was used for post-hoc analysis.

Multiple discriminant analysis was adopted to represent the biological relationships among the six Yemenite groups. This method allows the multiple measurements to be reduced to one or more canonical variate, i.e. weighted combinations having maximum potential for distinguishing between members of the different groups. The first canonical variate is the single weighted composite which of all the possible weighted composites provides maximum average separation between the groups regarding within-group variability. The second canonical variate is the weighted composite which, of all the possible weighted composites which are uncorrelated with the first, provides maximum average separation between the groups. Forward stepwise multiple discriminant analysis was performed utilizing the data of 11 craniofacial morphometric variables, in accordance with increasing evidence that head size and shape are more genetically determined than other body dimensions which, by contrast, are more '*environmentally sensitive*' (Carels et al., 2001; Kamakar et al, 2007; Jelenkovic et al., 2008; Sherwood et al., 2008; Martinez-Abadias et al., 2009). For variable selection, we chose $p \leq 0.01$ for F-to-enter and $p \leq 0.05$ for F-to-remove.

All statistical analyses were carried out with SPSS, version 16.0.

Results

The descriptive statistics of the considered variables in the total sample and in the six

geographical areas are listed in Table 1.

The observed differences in the mean values of all variables among the six groups are all highly statistically significant. Tukey's post-hoc test reveals higher statistically significant differences among four main groups: Tihamah, the Western Mountains and Central Plateau, the Southern Coast and Hadhramawt, the Eastern Mountains (Table 2). Tihamah is characterized by low values of stature and head length, while the values of the upper limbs and the width of the head are relatively higher. The Southern Coast group, on the other hand, has few significant differences from the other groups and, in particular, no differences at all from the Eastern Mountain and Hadhramawt groups. Similarly, the Western Mountain and Central Plateau groups show no differences. In general, the principal characteristics of the Central Plateau regard the relatively high stature and, similarly to the Western Mountain group, the width and depth of the thorax and the circumference of the head. However, the Central Plateau differs from the Western Mountain group (although not significantly) because of more elevated mean values of height, armspan and sitting height. The Eastern Mountains group shows significant differences from the other groups, except from the Southern Coast group, being most different from the Central Plateau. The group has the lowest values of armspan and arm length. Finally, the Hadhramwat group is statistically different from the Tihamah, and the Central Plateau and Eastern Mountains, while there are less differences when considering the Western Mountains and no difference from the Southern Coast.

The results evidence a net separation of the Tihamah, on one side, and the Western Mountains and Central Plateau, on the other. Furthermore, the Hadhramwat and the Southern Coast are different from the former two groups with the Eastern Mountains basically positioned between the Western Mountains and Central Plateau on the one side, and the Hadhramwat and the Southern Coast on the other.

These results were analysed by multiple discriminant analysis using the data of the more genetically determined variables. The obtained eigenvalues and values of Wilks' lambda indicate heterogeneity among the geographic areas. Table 3 reports the forward stepwise selection of the craniofacial morphometric measures. The number of variables selected in a stepwise discriminant analysis depends on the F-values fixed as the condition to enter or to remove the variables in the equation (Afifi & Clark, 1984; Sanna et al., 2007). In this study with $p \leq 0.01$ for F-to-enter and $p \leq 0.05$ for F-to-remove, 7 measures of the 11 craniofacial considered are in the equation: head circumference, length, width and height, nose height and width, and bizygomatic widths. Table 4

shows the eigenvalues and summary statistics of the forward stepwise discriminant analysis. Wilks' lambda (0.5016) indicates high intergroup heterogeneity: approx. F =26.403 (df=35; 5184; $p<0.0001$), requiring four of the canonical variates to account for significant intergroup variation. The first function explains 76.17%, the second function 16.03%, the third function 5.82%, and the fourth function only 1.66% of the total dispersion. Table 5 reports the standardized discriminant coefficients. The examination of the values suggests that head length and nose width have the maximum influence on the first discriminant function, head length and head circumference have it on the second, and head circumference and length have maximum influence on the third discriminant function.

The centroid of the Yemen groups derived from the forward stepwise discriminant analysis of the 11 craniofacial measures are shown in Figure 2. The first canonical variate well separates the groups with the Tihamah, Southern Coast and Hadhramawt on the one side, and the Eastern Mountains, Western Mountains and Central Plateau on the other. The second canonical variate separates the Tihamah, Western Mountains and Central Plateau from the Eastern Mountains, Southern Coast and Hadhramawt.

Thus, the multivariate analysis carried out using only the data of the more genetically determined variables confirm the general picture outlined in Tukey's post-hoc test (Table 2). In particular, from a morphometrical point of view, the Yemenite population seems to be composed of 3 morphologically distinct groups: the Tihamah, being the most different from all the other groups, the Eastern Mountain group which is positioned between the Southern Coast and Hadhramawt group on the one side, and the Western Mountains and Central Plateau, on the other.

Discussion

The average height (162.6 cm) of the Yemenite sample is congruent with the value of 162.0 cm obtained from the study of Cipriani's forms (Moggi-Cecchi, private collection) and the 163.7 cm obtained from 73 individuals from Kuwait (unpublished data), this latter value not being statistically significant. However, on average, they were found to be 3-6 cm lower than the mean values reported by Stegl and Baten (2009) for 6 coeval groups from the Middle-Eastern Arabic countries and Egypt. Furthermore, comparisons with the average values of many common variables with the coeval Arab populations of Libia (Danubio et al., 2011) highlight, in general, that the vertical dimensions of the North-African sample are higher than

the Yemenite population. Height, in particular, has average values which are approximately 5 cm higher.

It will be interesting to further deepen the study regarding this aspect by considering a cohort analysis to check for variations of average height over time. Indeed, the topic of secular changes is of special interest when considering biological distances in historical populations, as it may reflect possible different speeds of economic development. To this purpose, however, not only stature, but many other anthropometric parameters and some anthropometric indices, because of their 'eco sensitiveness', should be considered in relation to the available socioeconomic indicators (e.g. occupation).

Concerning the primary objective of this study, namely the morphometrical differences of the groups settled in the six geographical areas of Yemen, there are many aspects to be taken into consideration when interpreting the obtained results. Of interest are the biological distinctions between the "mountain" groups and the "plain/desert" groups. Furthermore, within this latter cluster, there are differences between the Tihamah and the groups of the Southern Coast, Hadhramawt and Easter Mountains.

The first aspect to consider is the role played by geographical factors. Yemen is one of the most elevated areas of the Arabian peninsula and it is characterized by a very distinct and varied geology. Considering the geographical criteria, the results are particularly coherent from an isolation/non-isolation point of view. The anthropological characteristics of the Western Mountain and Central Plateau groups are peculiar and similar because they form a group which is geographically isolated from the rest of the country. The Western Mountains, whose average altitude exceed 2000 m a.s.l., form a continuous mountain barrier which runs parallel to the Tihamah. Their western slopes drop sharply isolating the Tihamah, whose altitude is approximately sea level. On the other hand, their eastern slopes drop to 2000 m a.s.l. and, like the Central Plateau, they are particularly fertile territories which are principally populated by intensive agriculturists. The Eastern Mountain group is anthropologically and geographically isolated from the Western Mountains and the Central Plateau due to the presence of peaks which slope down gradually southwards to an altitude of 1000 m a.s.l. Here the rocky terrain transforms into a sandy desert area which borders with the Hadhramawt and the south coast. This territory is not particularly fertile and is inhabited by people involved in subsistence agriculture. From an anthropological point of view, these populations do not differ from the Hadhramawt. The south Coast and the Hadhramawt are

relatively different from an anthropological point of view despite their geographical proximity and the fact these areas are populated by people involved in the same type of commercial activities and stock raising. Finally, the Tihamah populations, which are principally involved in commerce, are anthropologically different from the groups in the mountain areas and the southern coastal zones.

Together with the geographical characteristics of the country, there are also some cultural factors that may have influenced the anthropological differentiation highlighted in this study. It is important to remember that the coastal zones, through the centuries, have been a commercial route for spices connecting the East, Africa and the Eastern Mediterranean. Furthermore, of note are the important commercial links among the coastal populations, in particular between the Tihamah and Ethiopia.

These facts, which are supported by historical sources (Seligman, 1917; Van Beek, 1970; Richard, 1984), are also indirectly confirmed in the coastal and southern populations of Yemen by the presence of genetic markers of African and Eastern origin. The African markers are principally present in the Tihamah and the Sothern coastal groups, whereas the Eastern markers (mainly from India) are found in the Hadhramawt. In fact, traditional genetic studies have evidenced how the Arab Yemenite population are basically Mediterranean with strong links with Saudi Arabia and Kuwait. All the data regarding the erythrocyte and serum markers point towards an intermediate position between the Eastern Mediterranean and Africa (Mourant, 1954; Maranjian et al., 1966; Mourant e Tills, 1967; Marengo Rowe et al., 1974; Tills et al., 1977; Saha et al., 1980; Sawhney et al., 1984). The results of these traditional genetical analyses have also recently been confirmed by studies on DNA markers. Further data can come from the genetic studies on the populations of the Arab Peninsula (Rowold et al., 2007; Alshamali et al., 2009; Abu-Amero et al., 2009: Destro-Bisol et al., 2010). Finally, worthy of note is the fact that most of the populations in Southern Yemen are Sunnites while most of the Northern Yeminite populations are Shiites. This could have constituted a barrier, which, considered together with the geography of the nation, possibly provoked a geographical microdifferentiation of the population.

The results of this study confirm the classification of the sample into anthropologically distinct groups according to geographical location, in agreement with what indicated by Coon. Nevertheless, considering the results of the ANCOVA analysis, applied using all the variables of the sample, together with the multivariate analysis applied to only the anthropometric variables considered to be more 'genetically determined', it is possible to distinguish 3 morphologically

distinct groups: the Tihamah, the Western Mountains and Central Plateau, and the Southern Coast and Hadhramawt. The Eastern Mountain group can be found in an intermediate position between the Southern Coast and Hadhramawt group on the one side and the Western Mountain and Central Plateau group on the other. These studies should be continued and confirmed by carrying out molecular investigations in future research.

Acknowledgments

Funds for the research came from MIUR 60% and the Istituto Italiano di Antropologia (www.isita-org.com). We are grateful to the Smithsonian Institution for providing access to its Archive and to Prof. Jacopo Moggi-Cecchi for allowing us to use the forms of Lidio Cipriani from his personal collection.

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Table 1. Descriptive statistics of the 19 anthropometric variables in the total sample and the 6 yemenite groups, and results of ANCOVA *(age in covariate; *** p<0.0001).*

Anthropometry	Total		Tihamah		West. Mount.		Centr. Plateau		East. Mount.		South. Coast		Hadhramawt		
	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	
N	1244		279		100		282		299		45		239		
Body															
Height	162.6	6.0	161.8	6.2	162.9	5.6	164.4	5.5	161.3	5.9	161.4	5.5	163.1	6.2	***
Armspan	167.9	7.4	170.4	7.8	166.3	7.5	168.2	6.8	165.6	7.2	166.4	6.6	168.5	7.1	***
Sitting height	84.0	3.4	83.1	3.3	83.6	3.6	84.5	3.3	83.7	3.2	83.9	3.0	85.1	3.4	***
Arm length	72.4	3.6	73.4	3.7	71.8	3.3	72.4	3.6	71.4	3.7	72.0	3.4	72.7	3.4	***
Biacrom. width	34.9	1.8	35.3	1.8	35.5	1.7	35.2	1.7	34.4	1.9	34.2	1.9	34.6	1.7	***
Bicristoil. width	27.3	1.4	27.7	1.5	27.3	1.3	27.6	1.3	27.1	1.3	26.9	1.3	26.9	1.4	***
Torax width	25.8	1.6	25.7	1.4	26.7	1.4	26.4	1.4	25.3	1.6	24.8	1.4	25.4	1.4	***
Torax depth	20.6	1.3	20.4	1.2	21.1	1.2	21.0	1.3	20.5	1.3	20.2	1.2	20.2	1.2	***
Head															
Circum.	53.9	1.6	53.4	1.5	54.5	1.5	54.4	1.4	53.6	1.6	53.7	1.4	54.1	1.8	***
Length	18.3	0.8	17.8	0.6	18.8	0.7	18.8	0.6	18.3	0.8	18.1	0.7	18.2	0.7	***
Width	14.5	0.6	14.9	0.5	14.4	0.5	14.3	0.5	14.4	0.6	14.7	0.6	14.6	0.6	***
Height	12.5	0.6	12.3	0.6	12.5	0.5	12.6	0.5	12.5	0.6	12.3	0.7	12.6	0.6	***
Min. Frontal	10.3	0.5	10.2	0.5	10.3	0.4	10.2	0.4	10.2	0.5	10.3	0.5	10.4	0.5	***
Face															
Total height	11.9	0.5	11.9	0.5	12.0	0.5	12.0	0.5	11.7	0.5	11.8	0.4	11.9	0.6	***
Super. height	7.1	0.4	7.0	0.5	7.2	0.4	7.2	0.4	6.9	0.4	6.9	0.4	7.0	0.4	***
Bizyg. width	13.3	0.5	13.6	0.5	13.2	0.4	13.2	0.5	13.1	0.5	13.2	0.6	13.2	0.5	***
Bigon. width	10.0	0.6	10.1	0.6	10.0	0.5	10.1	0.5	9.8	0.6	9.9	0.5	9.9	0.5	***
Nose height	5.4	0.4	5.4	0.3	5.5	0.4	5.6	0.4	5.3	0.4	5.2	0.4	5.3	0.4	***
Nose width	3.4	0.3	3.6	0.3	3.4	0.3	3.3	0.3	3.3	0.3	3.4	0.3	3.4	0.3	***

Table 2. Ethnic groups responsible for the observed differences of mean values and value of significance (HSD Tukey's post-hoc).

	Tihamah p	**West. Mount.** p	**Centr. Plateau** p	**East. Mount.** p	**South. Coast.** p	**Hadhramawat** p
Tihamah						
Height			0.001			
Armspan		0.002	0.004	0.001		
Sitting height			0.001			0.001
Arm length		0.013	0.008	0.001		
Biacrom. width				0.001	0.020	0.001
Bicristoil. width				0.001		0.001
Torax width		0.001	0.001	0.066	0.059	
Torax depth		0.002	0.001			
Head circum.		0.001	0.001			0.001
Head length		0.001	0.001	0.001		0.001
Head width		0.001	0.001	0.001		0.001
Head height			0.001	0.001		0.001
Min. Frontal						0.001
Face Total height			0.046	0.005		
Face Super height		0.023	0.001	0.074		
Bizyg. width		0.001	0.001	0.001	0.003	0.001
Bigon. width				0.001		0.011
Nose height		0.020	0.001			
Nose width		0.001	0.001	0.001	0.001	0.001
West. Mount.						
Height						
Armspan	0.002					
Sitting height						0.019
Arm length	0.013					
Biacrom. width				0.001	0.004	0.004
Bicristoil. width						
Torax width	0.001			0.001	0.001	0.001
Torax depth	0.002			0.006	0.005	0.001
Head circum.	0.001			0.002		
Head length	0.001			0.001	0.001	0.001
Head width	0.001				0.067	0.010
Head height						
Min. Frontal						
Face Total height				0.007		
Face Super height	0.023			0.001	0.005	0.002
Bizyg. width	0.001					
Bigon. width						
Nose height	0.020			0.004	0.001	0.003

Nose width	0.001					
Centr. Plateau						
Height	0.001			0.001		
Armspan	0.004			0.001		
Sitting height	0.001					
Arm length	0.008			0.018		
Biacrom. width				0.001	0.046	0.001
Bicristoil. width				0.001		0.001
Torax width	0.001			0.001	0.001	0.001
Torax depth	0.001			0.001	0.011	0.001
Head circum.	0.001			0.001		
Head length	0.001			0.001	0.001	0.001
Head width	0.001			0.051	0.007	0.001
Head height	0.001					
Min. Frontal						0.001
Face Total height	0.046			0.001		0.058
Face Super height	0.001			0.001	0.019	0.001
Bizyg. width	0.001			0.037		
Bigon. width				0.001		0.014
Nose height	0.001			0.001	0.001	0.001
Nose width	0.001					
East. Mount.						
Height			0.001			0.010
Armspan	0.001		0.001			0.001
Sitting height						0.001
Arm length	0.001		0.018			0.002
Biacrom. width	0.001	0.001	0.001			
Bicristoil. width	0.001		0.001			
Torax width		0.001	0.001			
Torax depth		0.006	0.001			0.057
Head circum.		0.002	0.001			0.001
Head length	0.001	0.001	0.001			
Head width	0.001		0.051			0.001
Head height	0.001					
Min. Frontal						0.002
Face Total height	0.005	0.007	0.001			0.020
Face Super height		0.001	0.001			
Bizyg. width	0.001		0.037			0.014
Bigon. width	0.001		0.001			
Nose height		0.004	0.001			
Nose width	0.001					0.047
South. Coast						
Height						

Armspan				
Sitting height				
Arm length				
Biacrom. width	0.020	0.004	0.046	
Bicristoil. width				
Torax width	0.059	0.001	0.001	
Torax depth		0.005	0.011	
Head circum.				
Head length		0.001	0.001	
Head width			0.007	
Head height				
Min. Frontal				
Face Total height				
Face Super height		0.005	0.019	
Bizyg. width	0.003			
Bigon. width				
Nose height		0.001	0.001	
Nose width	0.001			

Hadhramawat

Height				0.010
Armspan	0.054			0.001
Sitting height	0.001	0.019		0.001
Arm length				0.002
Biacrom. width	0.001	0.004	0.001	
Bicristoil. width	0.001		0.001	
Torax width		0.001	0.001	
Torax depth		0.001	0.001	0.057
Head circum.	0.001			0.001
Head length	0.001	0.001	0.001	
Head width	0.001	0.010	0.001	0.001
Head height	0.001			
Min. Frontal	0.001		0.001	0.002
Face Total height			0.058	0.020
Face Super height		0.002	0.001	
Bizyg. width	0.001			0.014
Bigon. width	0.011		0.014	
Nose height		0.003	0.001	
Nose width	0.001			0.047

Table 3 – Forward stepwise selection of 11 craniofacial measures with $p \leq 0.01$ for F-to-enter and $p \leq 0.05$ for F-to-remove.

Variables	Wilks' λ	F-remove (5, 1232)	p-level
Head lenght	0.5611	29.221	0.0000
Nose width	0.5557	26.577	0.0000
Head width	0.5244	11.178	0.0000
Nose height	0.5262	12.093	0.0000
Head circum.	0.5236	10.826	0.0000
Bizyg. width	0.5208	9.419	0.0000
Head height	0.5189	8.490	0.0000

Table 4 – Eigenvalues and summary statistics for the five discriminant functions obtained by forward stepwise procedure.

Function	Eigen-values	Percentual of variance	Canonical correlation	Function removed	Λ WIlks	χ^2	d.f.	p
1	0.645	76.03	0.626	0	0.502	853.110	35	0.000
2	0.136	16.19	0.346	1	0.825	237.472	24	0.000
3	0.049	5.78	0.217	2	0.937	80.032	15	0.000
4	0.016	1.89	0.125	3	0.983	20.558	8	0.008
5	0.001	0.11	0.031	4	0.999	1.155	3	0.764

Tabella 5 – Standardized coefficients for canonical variables.

Measures	**Root 1**	**Root 2**	**Root 3**	**Root 4**	**Root 5**
Head length	0.7147	-0.6574	-1.0840	-0.3247	0.1221
Nose width	-0.4600	-0.4545	0.1118	-0.2177	0.5184
Head width	-0.3864	0.0867	-0.5765	-0.5882	0.5018
Nose height	0.2052	-0.4819	0.2523	0.2618	0.4751
Head circum.	0.0005	0.5479	1.5694	-0.4856	-0.4029
Bizyg. width	-0.2461	-0.4615	0.0993	0.6682	-0.8403
Head height	0.1954	0.3462	0.2524	0.6175	0.4968
Eigenvalues	0.6452	0.1358	0.0493	0.0158	0.0009
Cum. Prop.	0.7617	0.9229	0.9802	0.9989	1.0000

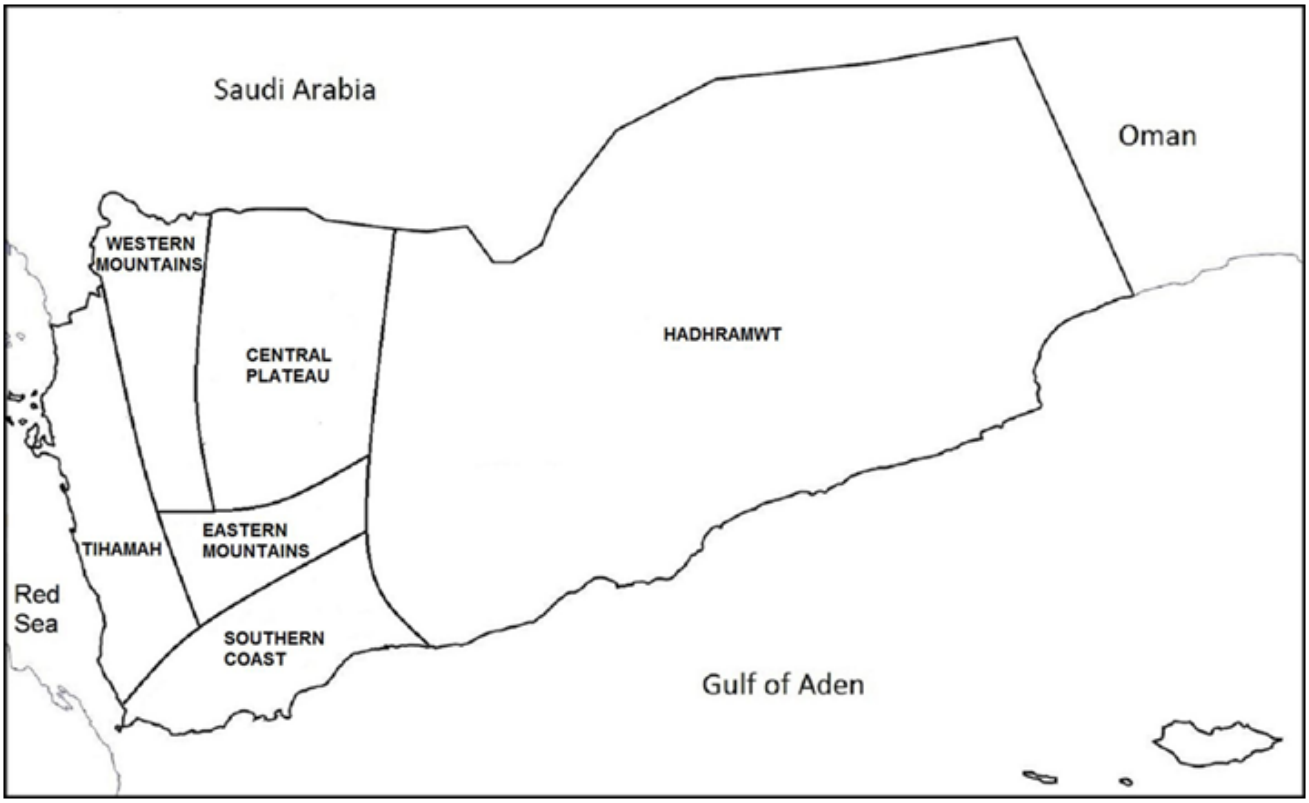

Figure 1: The map of Yemen divided in the 6 geographical regions reported by Coon (1933/34).

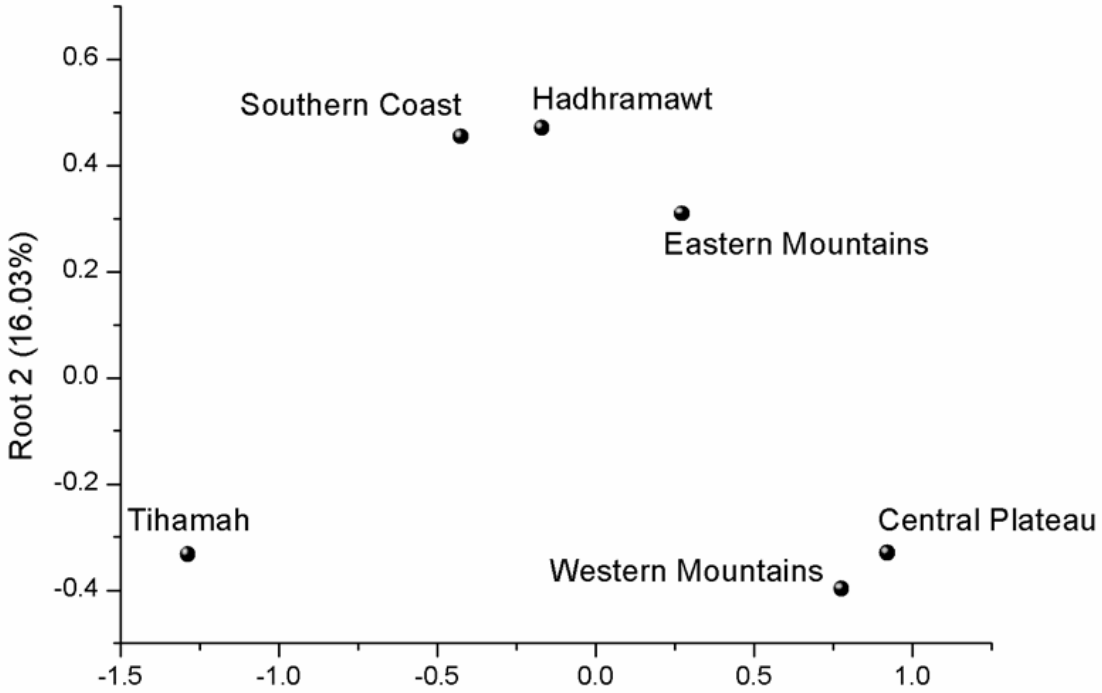

Figure 2: Results of multiple discriminant analysis performed on the data of the more genetically determined variables of the six conisdered groups.