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Climate-associated anthropometric variation between populations of the Niger bend

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Summary. A large set of measurements were taken on 512 women and 425 men belonging to ten populations of the Niger bend area, some of which live in the Sahelian, the other in the Sudanian climatic zones about 200 km apart. The two zones differ chiefly by a two-fold higher annual rainfall in the Sudanian zone. The pattern of differences in body weight, skinfold and limb circumferences suggests that the Sahelians allot proportionally more food and/or less physical work to women than the Sudanians. In one or both sexes, Sahelians have significantly longer lower limbs and forearms, larger hands and ears, a narrower face, and a higher and narrower nose. Sexual dimorphism of the shoulder-hip-width proportions is lower in the Sahelians, resulting from the Sahelian males, but not females, having wider hips, whereas Sahelians of both sexes have narrower shoulders. Multivariate analysis using D^2 distances shows Sahelian and Sudanian populations forming two separate clusters, with the exception of the Dogon. In the male sex, nose width and sitting height account for the total multivariate interpopulational variation; nose width alone separates the two zonal groups, again with the Dogon as an exception. The position of the Dogon near to Sudanian populations while living in the Sahelian zone is explained by their migration from the Sudanian zone a few centuries ago. Adaptative genetic response to climate is proposed as a partial explanation of the evidence presented.

1. Introduction

On a sub-Saharan African scale, many anthropometric variables are significantly correlated with climate. Hiernaux (1968) computed the correlation coefficients between various anthropometric means of male sub-Saharan African rural populations and five monthly or yearly averages of climatic variables related to either air temperature or moisture. Adding more recently published means to the previous set of data, Hiernaux and Froment (1976) revised the correlation coefficients between 15 measurements and the same five climatic variables. Only three measurements (calf circumference, chest depth and head length) failed to show a significant correlation with climate. Body-length measurements (stature, sitting height and upper limb length) were all correlated positively with the temperature of the hottest month and negatively with the humidity mixing ratio (Jackson 1961) of the driest month. Shoulder width was positively correlated with both annual rainfall and temperature of the coldest month whereas chest and hip widths were correlated with rainfall only, and negatively so, with coefficients similar in size to the positive one between shoulder width and rainfall (in the 0·43–0·45 range). The highest of these correlations, +0·50, was between sitting height and the temperature of the hottest month. Correlations of head and face measurements, though significant, were of a lower order of magnitude, the highest one (+0·42) being that between nose width and annual rainfall. Nose width was moreover negatively correlated with the temperature of the hottest month whereas nose height showed a negative correlation with all climatic variables.

While participating in a biomedical survey, the first author measured male and female samples of populations living in two separate latitudinal zones south of the bend of the Niger river, whose climate differed mostly by a considerably higher rainfall in the southern zone. This paper investigates in both sexes whether anthropometric differentiation in this area is associated with climatic variation between the two zones, and, if so, whether the associations conform to the general sub-Saharan African trends in the male sex outlined above. It will also compare sexual dimorphism in the two zones.

2. Materials and methods

Figure 1 shows the location of the ten populations studied: six in a northern strip about 200 km wide, and four in a southern strip about 400 km wide; the two strips are about 200 km apart. According to the F.A.O. (1962), the northern group is in the Sahelian climatic zone, and the southern group in the Sudanian zone. Extrapolating from Jackson's (1961) atlas, the northern zone has an annual rainall of about 400 mm and a mean annual temperature of 28°C, whereas the southern zone, with the same annual temperature, has a two-fold higher rainfall, of about 800 mm. Seasonal variation of monthly mean temperature is greater in the northern zone (9°, from 24 to 33°C) than in the southern zone (5°, from 26 to 31°C).

Table 1 lists the populations studied and gives the size of the male and female samples. All adult volunteers in the villages and camps visited were measured except relatives living in the same enclosure. Participation averaged about 50%, but differed between populations. In particular, no male Ful volunteered, and Dogon women were especially reluctant to participate. Estimated age ranged from 18 to 70 years, with 88% in the 20–60 year range. Two regions were visited in the Sahelian zone: the surroundings of the Oursi Pond, in the Oudalan department of Haute-Volta, and the flanks of the Sarnyere Mount, the most western peak of the Hombori Mount in Mali, some 200 km west of Oursi. Around and near the Oursi Pond were living communities of five ethnic

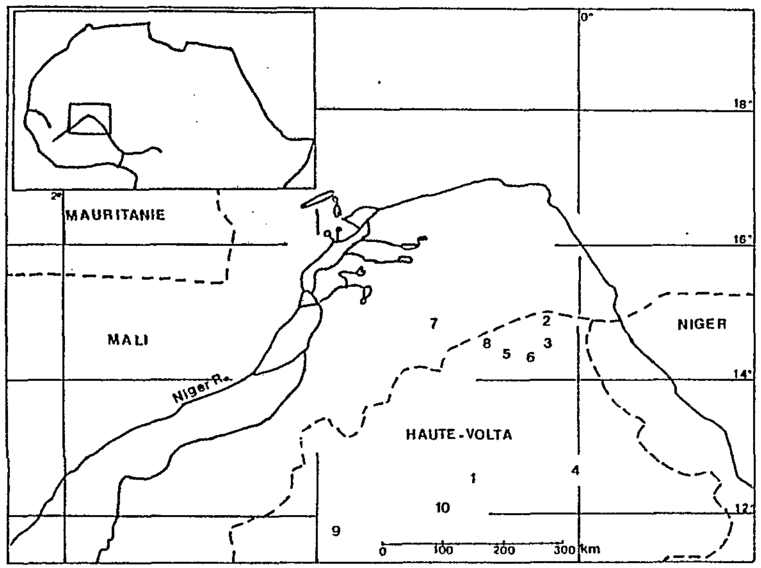

Figure 1. Location of the ten populations sampled, numbered as in table 1.

Table 1. Name and sample sizes of the ten populations grouped by climatic zone.

No.*†	Population	Sample size	
		M	F
Sahelian zone			
2	Bella	23	30
3	Rimaibe	38	22
5	Malebe	59	35
6	Sonrai	21	34
7	Dogon	145	51
8	Ful (Peul)	—	31
Sudanian zone			
1	Mossi of Donse	49	58
4	Gurmanche	30	90
9	Bwaba	33	42
10	Mossi of Kokologo	27	119

†Location of populations sampled; see figure 1.

groups: Sonrai, a peripheral offshoot of this numerous group of the Niger bend area; Malebe, members of this small group of Malian origin; Bella (or Iklan), former captives of the Imrad Udalen Tuareg, once from Sonrai, Kurumba, and Mossi villages; Ful (or Peul), a branch of this widely spread group, living an either fully nomad or semi-nomad life; and Rimaibe, former captives, and presently vassals, of the Ful in a social relationship similar to that of the Bella and Tuareg. In the Hombori region were visited all four Dogon villages on the slopes of the Sarnyere Mount and a camp of Ful Diallobe. The two samples of Ful were pooled. In the Sudanian zone, Mossi in Haute-Volta, the major ethnic group of the area, were visited in two places: at Donse, some 30 km north-east of Ouagadougou, the capital of the country, and Gubure-Sakoinse in the Kokologo region; Gurmanche were visited at Diabatu, and Bwaba (or Bwa or Bobo-Ule) at Moko, in the Black Volta basin.

The anthropometric programme consisted of 28 measurements in the males, 26 in the females (whose ears, deformed by ornaments, were not measured). It includes all measurements of the basic list recommended by I.B.P. (Tanner, Hiernaux and Jarman 1969) except the subscapular skinfold. I.B.P.-recommended techniques were followed. Circumstances did not permit measurement of stature in the Sonrai, or limb circumferences in the Bella.

The statistical analysis presented here consists of interethnic and interzone uni- and multivariate comparisons. In order to avoid giving an overwhelming weight to the two particularly large samples (male Dogon and female Mossi of Kokologo), unweighted means and variances of the Sahelian and Sudanian population groups were used in between-zone comparisons. Multivariate analysis was performed with the BMDP package.

3. Results

In each sex, table 2 gives the mean and standard deviation of each measurement in each population, and table 3 the unweighted means of means and standard deviations of the Sahelian and Sudanian groups of populations, the t tests of significance of the differences between these groups, and the biometric distances, d, from the Sahelian to the Sudanian group (i.e. the differences between their means divided by their common standard deviations). Only the intergroup significant differences will be indicated here. In body length and its two main components — sitting height and iliospinal height — the

Table 2. Means (upper figure) and standard deviations (lower figure) of all measurements in the ten populations. Identification numbers and sample sizes are given in table 1.

	1		2		3		4		5	
	M	F	M	F	M	F	M	F	M	F
Weight	58·2	51·3	56·5	51·0	62·2	56·2	59·2	51·7	59·6	54·7
(kg)	7·2	6·4	6·4	5·8	7·2	8·7	6·1	5·4	7·7	7·0
Stature	1677·7	1585·8	1684·2	1594·4	1725·1	1617·4	1720·4	1600·8	1687·5	1554·2
(mm)	59·9	55·4	74·6	59·3	68·5	70·9	47·7	56·0	75·7	59·6
Sitting H	824·1	792·2	836·9	818·2	863·3	826·5	872·7	810·3	841·1	783·5
(mm)	31·9	31·2	40·4	29·6	34·7	38·5	30·8	30·8	33·9	33·2
Iliac spine H	971·4	912·8	986·2	933·3	1012·2	958·7	1001·7	937·0	988·2	921·2
(mm)	44·0	39·4	50·0	52·3	54·1	45·6	32·8	40·9	52·3	42·9
Tibial H	462·4	432·5	477·2	438·4	486·5	454·6	477·0	429·2	471·1	426·4
(mm)	24·3	17·3	27·6	25·7	26·8	24·8	20·2	23·0	29·6	26·0
Upper limb L	800·9	735·2	786·6	737·0	804·8	760·3	805·5	739·9	788·1	733·4
(mm)	35·0	31·1	38·8	36·1	34·2	37·6	32·3	33·0	33·7	32·6
Arm L	335·9	309·3	330·4	307·1	335·2	312·5	335·0	309·6	327·6	305·6
(mm)	18·4	16·3	16·9	16·0	16·1	18·2	14·9	16·8	17·6	14·5
Forearm L	470·7	433·1	465·1	433·5	474·2	453·3	471·2	434·9	464·5	433·8
(mm)	20·8	20·0	16·9	22·0	16·1	21·8	14·9	21·9	17·6	22·4
Hand L	192·5	181·6	192·7	182·0	196·3	186·7	197·0	182·1	194·8	183·0
(mm)	9·1	8·2	11·6	7·8	9·8	9·6	9·7	8·4	9·2	9·8
Hand W	82·4	74·2	81·3	79·3	84·1	81·6	84·3	75·0	83·0	77·8
(mm)	3·9	4·4	4·1	3·7	3·7	4·1	3·8	3·8	3·6	3·5
Wrist W	52·3	48·8	52·9	51·0	54·0	53·1	53·1	47·8	52·4	50·3
(mm)	2·8	2·8	4·2	3·1	3·0	3·6	3·1	2·8	3·4	2·2
Knee W	89·4	80·3	90·9	83·1	91·7	84·0	90·5	80·7	89·3	81·3
(mm)	4·9	4·0	4·6	4·1	4·2	6·7	3·2	3·3	4·0	3·5
Ankle W	68·7	61·9	69·0	63·5	69·3	64·1	69·9	61·7	67·8	61·4
(mm)	3·4	2·8	5·0	3·2	4·4	3·7	3·7	3·3	4·2	3·8
Shoulder W	371·1	341·1	365·9	338·3	370·4	344·6	377·3	342·0	360·9	324·8
(mm)	20·1	15·8	15·8	24·9	23·6	22·0	16·6	14·6	19·3	24·1
Hip W	255·3	253·8	257·4	254·3	257·7	255·7	253·0	249·2	257·5	254·5
(mm)	13·1	11·6	18·2	11·2	13·8	13·6	10·9	11·7	15·6	12·8
Chest W	260·6	238·1	248·9	234·0	258·2	235·4	258·0	237·5	257·6	233·2
(mm)	13·3	11·2	13·8	11·1	14·4	15·3	10·8	13·0	18·7	14·8
Chest depth	190·9	171·3	189·9	176·1	192·3	177·6	195·5	170·5	189·8	176·5
(mm)	13·0	14·8	13·7	14·8	14·1	11·1	11·1	11·1	13·1	12·9
Upper arm C	264·5	264·4	—	—	281·6	276·6	276·9	266·6	283·9	278·2
(mm)	18·7	22·3	—	—	22·6	31·8	17·8	19·0	20·2	26·0
Calf C	316·1	313·1	—	—	326·8	314·0	323·5	312·2	328·0	315·0
(mm)	25·5	22·0	—	—	23·9	35·4	21·5	18·6	20·7	22·7
Tricip skinfold	60·8	92·8	48·3	96·3	58·2	123·4	51·9	90·6	57·3	127·7
(mm)	17·2	33·0	10·6	35·2	18·4	53·0	11·8	31·4	27·0	56·8
Head L	189·0	181·3	191·0	182·6	188·2	182·2	191·1	182·6	188·6	182·5
(mm)	6·4	6·3	5·4	6·4	6·1	6·3	6·9	5·5	5·3	6·5
Head W	139·5	134·5	145·0	138·5	141·6	134·8	141·8	135·2	142·1	135·7
(mm)	4·6	5·0	4·9	4·2	5·4	4·4	4·6	4·8	4·8	4·6
Bizygomatic W	132·8	124·7	137·9	126·3	135·1	126·2	136·4	128·6	134·4	125·3
(mm)	6·2	4·7	3·9	4·6	4·6	5·0	4·6	4·7	5·3	3·6
Face H	117·5	111·0	119·9	112·8	120·8	111·7	118·4	112·7	118·6	111·7
(mm)	7·2	5·8	8·4	5·5	8·1	8·0	5·8	6·8	5·8	6·8
Nose H	51·7	48·6	56·0	52·7	53·6	51·4	51·2	48·3	53·0	51·1
(mm)	3·9	3·5	4·4	2·9	3·8	4·1	3·9	4·1	4·0	4·0
Nose W	43·9	38·9	43·2	37·0	42·7	39·0	44·8	39·0	43·0	38·0
(mm)	3·4	2·6	3·7	2·3	3·1	1·9	2·9	2·3	3·0	2·6
Ear H	—	—	60·7	—	61·6	—	57·3	—	58·0	—
(mm)	—	—	4·8	—	5·7	—	4·8	—	4·9	—
Ear W	—	—	36·7	—	38·2	—	35·5	—	37·7	—
(mm)	—	—	2·8	—	2·9	—	2·1	—	2·5	—

	6		7		8		9		10	
	M	F	M	F	M	F	M	F	M	F
Weight	58·2	55·4	58·9	51·1	—	49·3	59·3	53·0	56·7	49·8
(kg)	8·3	8·2	6·9	5·7	—	5·6	6·4	6·4	7·4	5·6
Stature	—	—	1703·7	1582·8	—	1598·6	1706·6	1620·3	1689·3	1587·4
(mm)	—	—	65·8	60·6	—	51·8	72·6	49·2	65·4	57·6
Sitting H	844·3	804·9	851·5	797·5	—	815·0	853·5	817·8	845·8	804·5
(mm)	41·4	29·6	33·1	46·3	—	26·5	33·0	26·9	33·1	29·2
Iliac spine H	1013·5	952·6	988·4	931·1	—	937·1	995·5	941·4	990·2	933·3
(mm)	40·9	44·2	50·1	40·8	—	38·3	56·2	38·2	49·6	41·8
Tibial H	485·5	448·6	477·1	444·5	—	436·1	482·1	448·3	478·3	444·9
(mm)	20·3	22·9	24·9	21·4	—	19·8	25·7	21·8	24·4	23·2
Upper limb L	818·9	752·9	788·9	733·4	—	728·5	792·9	742·2	793·5	730·7
(mm)	32·5	35·6	35·7	31·1	—	28·0	36·4	29·0	44·8	34·0
Arm L	344·0	314·8	325·5	299·1	—	304·6	327·9	310·1	330·0	305·2
(mm)	13·5	15·2	16·4	14·8	—	13·7	15·4	13·3	20·2	15·3
Forearm L	481·6	444·2	467·0	436·9	—	431·0	466·1	434·4	468·0	431·0
(mm)	13·5	21·7	16·4	19·2	—	19·9	15·4	18·2	20·2	21·8
Hand L	200·1	183·6	194·0	183·3	—	179·5	194·2	182·2	193·1	179·3
(mm)	12·5	9·9	9·1	8·6	—	7·7	10·6	8·2	11·1	9·0
Hand W	83·7	77·8	82·8	77·2	—	75·2	85·2	76·3	83·0	73·0
(mm)	4·7	3·8	6·6	4·3	—	3·0	3·9	3·8	3·7	3·9
Wrist W	54·0	51·2	53·7	50·2	—	49·1	54·1	49·5	53·2	47·8
(mm)	4·1	2·8	2·7	3·1	—	3·3	3·0	2·9	2·7	2·6
Knee W	90·2	82·0	89·6	81·3	—	79·2	89·7	82·1	89·4	79·7
(mm)	5·0	3·6	3·8	3·6	—	4·3	4·3	3·8	3·5	3·7
Ankle W	67·7	61·7	68·9	63·3	—	61·3	69·1	63·7	67·7	60·5
(mm)	6·2	3·8	3·7	3·2	—	4·0	3·7	3·3	2·8	3·5
Shoulder W	372·5	334·8	371·1	335·3	—	333·0	382·8	343·3	369·2	340·2
(mm)	27·8	16·2	18·7	15·7	—	13·2	20·6	14·7	19·9	17·6
Hip W	261·7	250·5	253·9	246·5	—	251·7	250·9	257·4	253·3	254·7
(mm)	15·9	15·0	12·4	15·9	—	13·5	15·1	15·5	14·8	13·4
Chest W	256·3	234·1	259·8	233·1	—	229·4	261·2	239·6	255·1	235·1
(mm)	18·7	11·9	12·6	11·6	—	13·1	13·9	14·5	13·3	12·1
Chest depth	186·5	177·4	186·9	176·6	—	161·6	194·1	174·5	193·4	174·6
(mm)	11·3	12·8	11·5	10·2	—	10·7	15·8	9·2	12·7	12·1
Upper arm C	265·4	274·0	274·1	267·2	—	252·1	275·8	270·1	268·1	259·2
(mm)	21·0	25·6	21·2	17·9	—	24·8	17·2	23·1	19·2	17·6
Calf C	307·4	313·7	336·0	323·3	—	297·7	326·2	313·0	312·8	309·8
(mm)	22·2	19·5	23·4	20·5	—	27·7	18·1	22·7	16·3	22·3
Tricip skinfold	43·1	121·4	51·1	92·2	—	108·3	47·1	88·1	48·8	84·1
(mm)	6·4	47·1	12·9	31·0	—	36·6	13·8	35·8	13·8	26·2
Head L	186·9	180·3	188·1	178·4	—	185·4	191·7	184·8	189·8	182·6
(mm)	6·9	6·9	6·7	8·5	—	5·0	6·3	5·3	5·7	5·7
Head W	140·2	134·9	139·8	134·0	—	135·9	140·9	136·4	140·1	134·3
(mm)	7·1	6·1	4·9	4·6	—	6·0	5·6	4·9	4·4	5·1
Bizygomatic W	133·6	123·6	134·9	126·5	—	121·4	137·0	127·3	135·0	125·3
(mm)	6·4	4·9	5·0	4·1	—	5·5	5·1	4·4	6·4	4·9
Face H	121·1	112·6	117·4	109·1	—	110·3	119·9	115·7	115·1	108·3
(mm)	6.4	5·7	6·5	15·0	—	7·2	7·9	5·9	5·0	5·6
Nose H	54·0	49·5	50·4	48·1	—	50·8	51·8	50·4	48·3	46·2
(mm)	3·3	4·2	4·1	3·5	—	4·7	3·9	3·8	3·3	3·2
Nose W	43·1	38·0	43·2	38·9	—	36·3	44·3	38·6	43·8	38·2
(mm)	3·3	3·2	3·1	3·3	—	2·1	3·1	2·6	3·2	2·3
Ear H	—	—	58·5	—	—	—	58·2	—	60·0	—
(mm)	—	—	4·7	—	—	—	4·6	—	4·3	—
Ear W	—	—	36·0	—	—	—	35·2	—	36·3	—
(mm)	—	—	2·2	—	—	—	2·2	—	3·2	—

H, height; l, length; W, width; C, circumference.

only significant difference is a longer lower limb of the Sahelian females. No difference appears in upper limb length, but the Sahelian females have longer forearms and hands. They have broader wrists, hands and knees. They are heavier and have a thicker tricipital skinfold. Their arm circumference is larger, as is also that of the Sahelian males. These also show a larger calf circumference. Sahelians of both sexes have narrower shoulders, and Sahelian females a narrower chest too, whereas Sahelian males show a lower chest depth and wider hips. Sahelian males have a shorter and wider head and a higher face, whereas Sahelian females have a narrower face. Nose measurements show the same pattern of differences in both sexes: the Sahelians have a higher and narrower nose. The ears, measured in the males only, are higher and wider in the

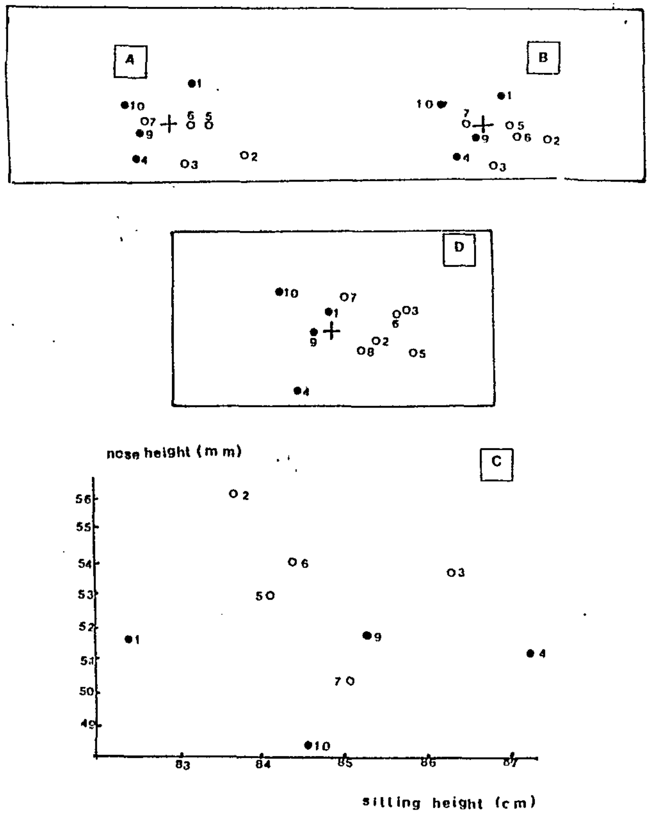

Figure 2. A, B, and D, two-dimensional scatters from matrices of D^2 distances between the nine male samples (A and B) or the ten female samples (D). Sets of variables: A, 17 measurements (all except those of the upper limb, limb perimeters, and joint widths); B, 10 cephalic and longitudinal body measurements; D, 16 measurements (very similar to the set used in A). C, Scatter of the nine male samples on a nose height/sitting height graph. ○ Sahelian zone, ● Sudanian zone.

Table 3. Unweighted means and standard deviations of the measurements of the Sahelian and Sudanian population groups, *t* test of significance of the differences, and *d* distances from the Sahelian to the Sudanian groups.

Variable	Males								Females							
	Sahelian zone			Sudanian zone					Sahelian zone			Sudanian zone				
	N	Mean	SD	*N*	Mean	SD	*t*	*d*	*N*	Mean	SD	*N*	Mean	SD	*t*	*d*
Weight (kg)	286	59·1	7·3	139	58·3	6·7	1·11	0·11	203	52·9	6·9	309	51·4	6·0	2·54*	0·23
Stature (mm)	265	1700·1	71·3	139	1698·5	62·1	0·23	0·02	169	1589·5	60·7	309	1598·6	54·6	1·62	−0·16
Sitting H	286	847·4	36·8	139	849·0	32·2	0·46	−0·05	203	807·6	34·6	309	806·2	29·6	0·47	0·04
Iliac spine H	286	996·6	49·7	139	989·7	46·4	0·23	0·14	203	939·0	44·2	309	931·1	40·1	2·05*	0·19
Tibial H	286	479·5	26·0	139	474·9	23·7	1·82	0·18	203	441·4	23·5	309	438·7	21·5	1·32	0·12
Upper limb L	286	797·5	35·0	139	798·2	37·4	0·18	−0·02	203	740·9	33·7	309	737·0	31·8	1·31	0·12
Arm L	286	332·5	16·2	139	332·2	17·4	0·17	0·02	203	307·3	15·5	309	308·5	15·5	0·86	−0·08
Forearm L	286	470·5	16·2	139	469·0	18·0	0·83	0·09	203	438·8	21·2	309	433·3	20·5	2·91**	0·26
Hand L	286	195·6	10·5	139	194·2	10·1	1·32	0·14	203	183·0	8·9	309	181·3	8·4	2·70**	0·20
Hand W	286	83·0	4·7	139	83·7	3·8	1·63	−0·16	203	78·1	3·8	309	74·6	4·0	10·00**	1·24
Wrist W	286	53·4	3·5	139	53·2	2·9	0·63	0·06	203	50·8	3·0	309	48·5	2·8	8·52**	0·79
Knee W	286	90·3	4·3	139	89·7	4·0	1·40	0·14	203	81·8	4·4	309	80·7	3·7	2·89**	0·27
Ankle W	286	68·5	4·8	139	68·8	3·4	0·75	−0·07	203	62·5	3·6	309	61·9	3·2	1·94	0·17
Shoulder W	286	368·2	21·5	139	375·1	19·4	3·32**	−0·34	203	335·1	17·1	309	341·6	15·7	4·09**	−0·40
Hip W	286	257·6	15·3	139	253·1	13·6	3·08**	0·31	203	252·2	13·7	309	253·8	13·1	1·31	−0·12
Chest W	286	256·2	15·8	139	258·7	12·9	1·74	−0·17	203	233·2	13·1	309	237·6	12·8	4·62**	−0·42
Chest depth	286	189·1	12·8	139	193·5	13·3	3·24**	−0·34	203	174·3	12·2	309	172·7	12·0	1·47	0·13
Upper arm C	263	276·2	21·3	139	271·3	18·2	2·41*	0·25	173	269·6	25·6	309	265·1	20·6	1·98*	0·19
Calf C	263	324·5	16·1	139	319·9	21·3	2·23**	0·24	173	312·7	25·8	309	312·1	21·5	0·26	0·03
Tricip skinfold	286	51·7	16·7	139	52·1	14·3	0·26	−0·03	203	111·5	44·3	309	88·9	31·8	6·28**	0·59
Head L	286	188·6	6·1	139	190·4	6·3	2·77**	−0·29	203	181·9	6·7	309	182·8	5·7	1·58	−0·14
Head W	286	141·7	5·5	139	140·6	4·8	2·12*	0·21	203	135·6	5·6	309	135·1	4·9	1·11	0·10
Bizygomatic W	286	135·2	5·1	139	135·3	5·6	0·18	−0·02	203	124·9	4·7	309	126·5	4·7	3·81**	−0·34
Face H	286	119·6	7·1	139	117·7	6·6	2·71**	0·32	203	111·4	6·7	309	111·9	6·0	0·71	−0·07
Nose H	286	53·4	3·9	139	50·7	3·8	6·92**	0·70	203	50·6	3·9	309	48·4	3·7	6·29**	0·58
Nose W	286	43·0	3·2	139	44·2	3·2	3·64**	−0·37	203	37·9	2·6	309	38·7	2·4	3·48**	−0·31
Ear H	265	59·7	5·0	90	58·5	4·6	2·11*	0·25	—	—	—	—	—	—	—	—
Ear W	265	37·1	2·6	90	35·7	2·5	14·00**	0·54	—	—	—	—	—	—	—	—

H, height; L, length; W, width; C, circumference.

Sahelians. A relatively higher order of magnitude of interzone difference (a *d* of 0·40 or more) is attained in the females by hand, wrist, shoulder and chest widths, and in the males by nose height and ear width.

Table 4. Male mean/female mean ratio of body height, trunk and limb lengths, and girdle widths in the Sahelian and Sudanian zones.

	Male/female ratio	
	Sahelian zone	Sudanian zone
Stature	1·07	1·06
Sitting H	1·05	1·05
Iliac spine H	1·06	1·06
Upper limb L	1·08	1·08
Shoulder W	1·10	1·10
Hip W	1·02	1·00

H, height; W, width; L., length.

Table 4 compares the sexual dimorphism of the two zonal groups in body height, trunk and limb lengths, and girdle widths by using the male mean/female mean ratio. The Sahelians are somewhat more dimorphic in stature than Sudanians, and more markedly so in hip width, in which Sudanian males and females are approximately equal whereas male Sahelians exceed females by 5 mm.

The tests of normality of distributions and homogeneity of variances and correlation coefficients, whose values are given in Froment's (1983) thesis, showed only a moderate proportion of cases of departure from the conditions of normality and homogeneity required for a strictly correct use of Mahalanobis' D^2 analysis. In particular, the distribution of body weight showed a significant skewness in only one of the populations in each sex; only the tricipital skinfold showed a high proportion of cases of significant skewness (seven populations in each sex).

Matrices of D^2 were computed from various sets of measurements. The algorithm used worked stepwise, starting with the measurement accounting for the largest discrimination between the ten (in the female sex) or nine (in the male sex) populations, then proceeding with the measurement contributing next highest to the residual differentiation, and so on. The various matrices of distances and the biometrical maps drawn from their two-dimensional reduction are in Froment (1983). In the male sex, the maps were very similar whatever the set of measurements. The map obtained from ten cephalic and longitudinal body measurements (figure 2B) closely resembles that obtained from a set of 17 variables excluding the upper limb measurements, limb circumferences and joint widths only (figure 2A). In the latter set, six variables contributed significantly (by rank order: nose height, sitting height, shoulder width, tricipital skinfold, hip width, and head breadth) whereas in the former set, only two did so: the first two of the latter set, nose height and sitting height, in the same rank order. Plotting the nine populations on a nose height/sitting height graph (figure 2C) produces a map closely resembling those obtained from multivariate distance analysis.

In the female sex also, the maps obtained from different sets of measurements were very similar. Figure 2D shows the map computed from a set of 16 measurements closely similar to that on which figure 2A is based. Twelve measurements contributed significantly (by rank order): bizygomatic width, wrist width, tibial height, nose height, iliac spine height, sitting height, body weight, chest depth, head length, tricipital skinfold, shoulder width and hip width. The general pattern of differentiation appears

to be roughly similar in the two sexes when the maps of male and female samples ar compared. In both sexes, without any evidence of clustering, the population inhabiting the same climatic zone occupy a limited part of the biometrical map. Th two zonal areas do not overlap, with one exception: the Dogon (population No. 7), wh live in the Sahelian zone, are nearer to Sudanian populations than to any one of the own zone.

4. Discussion

The measurements known to be sensitive to the balance between food intake an energy expenditure during adulthood (skinfold, body weight and limb circumference show a significant superiority of the Sahelian over the Sudanian males in limb circun ferences, but not in weight or tricipital skinfold (indeed, this skinfold is insignificantl less in the former). This suggests that the Sahelian males have a larger muscle mass an a slightly lower fat mass. The picture is different in the female sex. Sahelian females a superior in tricipital skinfold over the Sudanian females by the second highest value *d*. Computed from zonal means, the lean arm diameter (arm circumference ÷ – tricipital skinfold, is lower in the Sahelian than in the Sudanian females (74·7 again 75·5) which is the inverse of the male difference (82·8 against 81·2 in the Sahelian an Sudanian males, respectively). Thus as assessed by the measurements cited above, tl two sexes show an inverse pattern of difference in body composition between the tv zones: in the Sahelian zone, females have more fat and less muscle, whereas males ha more muscle and less fat.

What this biometrical picture suggests is this: when the two sexes are pooled, tl two zonal population groups look roughly similar in the level of their balance betwe energy input and expenditure during adulthood. They presumably differ in the shari of physical work and food between the sexes: the Sahelian communities seemingly all a lesser part of their work and a larger part of their food to women than the Sudani communities do. An explanation of such a behavioural difference in terms of cultur influence apparently stands to reason. The Sahelian zone has been much mo influenced by the Tuareg cultural system than the Sudanian zone; the Tuareg society known for the high aesthetico-sexual value it assigns to fatty women; the Tuar cultural influence may therefore be the immediate cause of the biometrical patte disclosed here. However, climate might be a more remote cause of this pattern, to tl extent to which the Tuareg system of values concerning the sharing of work and fo between sexes is a (possibly adaptive) response to more arid conditions, and/or tl Sudanian way of life is a response to wetter conditions, a question whose answer wou require a thorough study.

On the geographical scale of this study, the sub-Saharan African tendency stature to be lower where the climate is wetter is not expressed. However, the tenden of the lower limbs to be relatively longer where the climate is drier and has higher pea of heat shows itself in the female sex. Women in the Sahelian zone not only have long legs, but also, and more markedly so, longer forearms, and longer and wider hand This tendency to longer limbs, and particularly long distal limb segments, in the Sah can be explained in terms of the physiological considerations put forward by Wein (1977): both convection and evaporation coefficients, expressed per unit area, approa constant values for large surfaces but increase rapidly as the diameter of the limbs limb segments are reduced below a diameter of about 10 cm. Since evaporation of swe is more efficient as a cooling mechanism where the air is drier, the longer limb segment and the larger hands, of the Sahelian females may be seen as adaptive to the dri climate, with higher peaks of heat, where they live.

Such a morphological differentiation between the two zones is absent in the male sex. Perhaps this indicates a higher ecosensitivity of the females in this aspect of morphology. However, Sahelian males show larger measurements of the thinnest prominent parts of the body: the ears, in conformity with the preceding considerations. This difference in ear size also conforms with Allen's rule which asserts a tendency of prominent parts to be larger in hotter conditions among varieties or related species of homoeotherms, especially if dryness is added to heat in the determining conditions. It is unfortunate that the ear could not be measured in females.

The tendency of sub-Saharan African males to have narrower shoulders and wider hips in a drier climate manifests itself when Sahelian and Sudanian males are compared. Sahelian females also show narrower shoulders, but not wider hips. As a consequence, the sexual dimorphism in shoulder-hip-width-proportions is lower in the Sahelian zone: the general male superiority in biacromio-biiliac index amounts to 10 units in this zone (between 143 in the male and 133 in the female sex) against 13 units in the Sudanian zone (148 and 135). The mechanism of the relation of climate with this pattern of difference is not known.

In agreement with the inverse correlations of nose height and width with rainfall in the sub-Saharan African male, the nose of the Sahelians is higher and narrower, in both sexes, than that of the Sudanians. Of all measurements taken, nose height is that which shows the greatest distance between Sahelian and Sudanian males. The relatively strong association of nose measurements with annual rainfall in the Niger-bend area is coherent with the moistening role of the nasal mucosa advocated by Weiner (1954) as the physiological determinant of the correlations between nose measurements and air moisture.

The wider face of the Sudanian females also agrees with the sub-Saharan African tendency: a positive correlation of bizygomatic width with rainfall. Head width is the only cephalic measurement to show a significant difference between Sahelians and Sudanians (but in the male sex only) whose sign is contrary to that predicted from the subcontinental correlations: the head of the Sahelian males is broader, whereas the general tendency is to a narrower head in a drier climate. It is also longer, whereas head length shows no significant correlation with any climatic variable at the subcontinental scale.

Four significant differences remain to be discussed. All are observed in one sex only. Two concern the chest, which is narrower in the Sahelian female like the shoulder girdle, an association explicable by anatomy, and flatter in the Sahelian male, apparently a component of the general slenderness of body build in hot arid environments. Both remaining differences concern bone widths in the female sex: Sahelian females show a wider wrist, obviously linked anatomically to their wider hand, and a wider knee, possibly a result of their greater body mass.

The associations between anthropometric measurements and climate in the Niger-bend area are strong enough to make, in each sex, the two population groups occupy separate regions of the hyperspace of multivariate distances, the only exception being the Dogon male sample. The partly different patterning of interzone univariate differences in the two sexes does not prevent their showing a roughly similar scattering of the populations in the hyperspace. Most probably, this difference in patterning is a determinant of the between-sex differences in set and order of discriminative variables in multivariate analyses. It may not be the only one, since multivariate analysis aims at differentiating the nine or ten populations, and not the two population climatic groups.

This latter point is illustrated in the male sex by the fact that of the two most disci native measurements in the stepwise multivariate analysis which produced figure the only ones to contribute significantly to the total variation are first nose heigh the measurement showing the largest univariate distance between Sahelian Sudanian males, and second sitting height, in which the two population groups do differ significantly. Figure 2C clearly shows how their combination generat scattering of the nine male samples similar to the two-dimensional projection of location in the hyperspace of D^2s: Sahelians and Sudanians occupy non-overlap segments of the nose-height range, with the exception of the Dogon, whereas the p lations of the two groups are intermingled along the sitting-height axis, with Sahelian range totally included within the wider Sudanian range.

The location of the Dogon near to Sudanian populations on figures 2A–C sho the scatter of male samples and the less marked departure of the female Dogon other Sahelian samples on figure 2D themselves indicate an explanation in term climatic influence. The traditions recorded by Griaule and Dieterlein (1965) point migration of the ancestral Dogon from a more southerly region in the present M area to their current habitat, starting in the fifteenth century AD. The findings made number of caves in the cliffs of the Dogon territory are consistent with their first ar at that time (Huizinga, Bedaux and van der Waals 1979). If their origin is the Suda zone is real, the Dogon seemingly retained anthropometric affinities with the p lations of their original habitat.

If the latter conclusion is right, it implies that the separation of Sahelians Sudanians shown by multivariate anthropometric analysis is largely of genetic nat rather than resulting from the influence of climate on the phenotypic expression of genotype. This favours explaining the anthropometric distance between Sahelians Sudanians of the Niger-bend area in terms of genetic response to climate. It may be genes flow more freely within than between climatic zones, with perhaps past or pre sources of genetic radiation such as those from the Tuareg in the north and Mossi in south. Such a pattern would only maintain a genetic differentiation of Sahelians Sudanians, the ultimate explanation of which would require considering ada response to climate as one, or even the major one, of its mechanisms.

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Zusammenfassung. Ein großes Ensemble von Maßen wurde bei 512 Frauen und 425 Männern von zehn Bevölkerungen des Nigerbogengebiets genommen, von denen einige in der Sahelzone leben, die anderen in den Klimazonen des Sudan in Entfernung von etwa 200 km. Die beiden Zonen unterscheiden sich hauptsächlich durch einen doppelt so hohen jährlichen Niederschlag in der Sudanzone. Die Verteilung der Unterschiede des Körpergewichts, der Hautschichtdicke und der Gliedmaßenumfänge legt nahe, daß die Sahelbewohner den Frauen proportional mehr Nahrung und/oder weniger körperliche Arbeit zumessen als die Sudanbewohner. In einem oder beiden Geschlechtern haben die Sahelbewohner signifikant längere Gliedmaßen und Unterarme, größere Hände und Ohren, ein schmaleres Gesicht und eine höhere und schmalere Nase. Der Geschlechtsdimorphismus der breiten Proportion zwischen Schulter und Hüfte ist bei den Sahelbewohnern niedriger, was aus den breiteren Hüften der Männer, nicht jedoch der Frauen resultiert, wohingegen die Sahelbewohner beider Geschlechter schmalere Schultern haben. Die multivariate Analyse mittels des D^2-Abstandes zeigt, daß die Sahel- und Sudanbevölkerungen zwei getrennte Cluster bilden, mit der Ausnahme der Dogon. Im männlichen Geschlecht erklären Nasenbreite und Sitzhöhe die gesamte multivariate Variation zwischen den Bevölkerungen; die Nasenbreite allein trennt die beiden Zonengruppen, wieder mit der Ausnahme der Dogon. Die Position der Dogon nahe den sudanischen Bevölkerungen, jedoch bei einem Siedlungsgebiet in der Sahelzone, wird durch ihre Wanderung aus der Sudanzone vor wenigen Jahrhunderten erklärt. Eine adaptive genetische Antwort auf das Klima wird als Teilerklärung der vorgestellten Befunde vorgeschlagen.

Résumé. Un grand ensemble de mensurations ont été prises sur 512 femmes et 425 hommes de dix populations de la boucle du Niger, dont certaines vivent en zone climatique sahélienne, les autres en zone soudanienne, à environ 200 km de distance. Les deux zones diffèrent surtout par une pluviosité annuelle deux fois plus élevée en zone soudanienne. La configuration des différences en poids du corps, plis cutanés et périmètres de membres suggère que les sahéliens allouent proportionnellement plus de nourriture et/ou moins de travail physique aux femmes que les soudaniens. Dans l'un des sexes ou les deux, les sahéliens ont significativement des membres inférieurs et des avant-bras plus longs, des mains et des oreilles plus grandes, une face plus étroite et un nez plus haut et plus étroit. Le dimorphisme sexuel des proportions largeur des épaules-largeur des hanches est moindre chez les sahéliens, du fait de ce que les hommes sahéliens, mais non les femmes, ont des hanches plus larges, alors que les sahéliens des deux sexes ont des épaules plus étroites. L'analyse multivariée des deux sexes à l'aide des distances D^2 montre que les populations sahéliennes et soudaniennes forment des sous-ensembles séparés, à l'exception des Dogon. Dans le sexe masculin, la largeur du nez et la taille assis assument la totalité de la variation multivariée interpopulationnelle; à elle seule la largeur du nez sépare les deux groupes zonaux, à nouveau à l'exception des Dogon. La position des Dogon à proximité des populations soudaniennes alors qu'ils vivent en zone sahélienne s'explique par leur migration à partir de la zone soudanienne il y a quelques siècles. Une réponse génétique adaptative au climat est proposée comme explication partielle de l'information présentée.